DISCOVERY

Manufacture of nylon at the B.N.S.
factory, Pontypool (see "The Mole-
cular Architecture of High Polymers")

APRIL 1954　　　**2/-**

THE PROGRESS OF SCIENCE

ATOMIC ENERGY: THE NEXT STEP

The second reading of the Atomic Energy Authority Bill transferring the control of atomic energy development from the Ministry of Supply was an exciting occasion. For it was announced that a new and powerful atomic reactor is to be built at Dounreay, which will a great deal more than put this hamlet on the map.

Giving this news to the House of Commons, the Minister of Works (Sir David Eccles) said the Dounreay power pile will be "a big, fast reactor of the 'breeder' type". As a special precaution against any leakage of radioactivity from the pile a large spherical shell will surround it—and as Sir David said this "really will be a Dome of Discovery", for this project will indeed be a great advance in the field of atomic power engineering—it "will become a world-famous pioneer among the plants which provide electricity in the next generation" was the Minister's comment in this connexion. When asked when building operations would start, Sir David replied that their intention is "the sooner the better". Survey work has gone on already, and the Ministry of Works will start construction just as soon as they can. The job will be done to the specifications of the men of the Atomic Energy Development Authority who are temporarily in charge. It is anticipated that this atomic power station when it is completed will provide employment for about 600 men, and of these about half will be recruited locally.

A number of other interesting points were made by the Minister during his speech which opened the debate on the new atomic bill. He gave some figures for expenditure on atomic energy work. He said that in the first six years—1946 to 1951—over £100 million was spent by the Ministry of Supply. Current expenditure on atomic energy is at the rate of over £50 million a year. He anticipated that the rate of expenditure will increase. (The U.S. Atomic Energy Commission has already spent 7500 million dollars on her atomic projects, and has appropriated a further 2500 millions).

The Minister emphasised that the British investment in this field is now changing its character, for the programme is becoming less like a laboratory and more like an industry. Up till now most of this work has been carried out in deadly secret, nine-tenths of the total effort being concerned with atomic weapons. Said Sir David, "Now a change is taking place, and there is no need to develop the peaceful uses of fissile material in the dark. Parliament and industry ought now to know what is going on." He continued:

> The top scientists and engineers agree with the Government that there is now a strong case for bringing them together round the board room table where they can examine the programme as a whole and make joint recommendations which will be upon the responsibility of all the members of the Authority. It seems to me that the fact that these men favour the kind of organisation that we shall get under the Bill is a very strong argument for the principle of the Bill itself.

The Minister of Works referred to the board of the Atomic Energy Authority, which will consist of a chairman, and not fewer than six and not more than ten members—some of whom will be part-time. To the chairman, Sir Edwin Plowden, the Minister expressed the Government's wish for success in what must be one of the most responsible and romantic posts open to a British subject. The Lord President of the Council (Lord Salisbury) is proposing to invite Sir John Cockcroft, Sir Christopher Hinton and Sir William Penney to join the board as founder-members with executive duties in distinct sections of the Authority's work and they will continue to be the heads of their respective services as well as board members.

An idea of the scale of capital investment in atomic installations was given by the Minister when he stated that for every 200 men employed throughout the project, that is from the most senior man to the most

junior, there is already £1 million invested in plant, equipment and buildings.

The Authority, said Sir David, will maintain established contacts with industry and the universities, and it will be placing research contracts with both. The Minister also announced a new development of special interest. Already in hand is a scheme to set up a *school of reactor technology*, where industrial engineers can learn about the fundamental principles of reactor design. (Readers will recollect that in the last issue of DISCOVERY the first textbook on this subject, entitled *Introduction to Nuclear Engineering* and edited by Richard Stephenson of Oak Ridge, was announced.) This reactor school was described by the Minister as the seed of great things to come; a generation from now, we may hope, there will be atomic power stations all over the world operated by men trained in Britain. The Commonwealth countries have been sending scientists to Harwell, and the Minister looked forward to the time when the men who will pioneer atomic energy projects in various parts of the Commonwealth arrive in Britain to study reactor design.

Sir David also looked forward to the day when the

This diagram shows the relationship of the three British atomic factories.

British Electricity Authority and the Scottish electricity boards will buy atomic fuel from the Atomic Energy Authority, and operate their own atomic power generators. This development cannot, of course, take place until *after* experience has been gained in the operation of the two prototype atomic power stations at Calder Hall, Cumberland, and Dounreay, Caithness.

The Minister of Works concentrated on the big issues involved in the new legislation, and left it to the Lord Privy Seal (Mr. Crookshank) to deal with some of the finer details and to reply to questions raised during the debate. The new bill says that "*The Lord President of the Council shall have power to give the Authority such directions as he may think fit,*" but Mr. Crookshank was at pains to point out that this phrase is properly qualified: the Lord President is not to regard it as his duty "*to intervene in detail in the conduct by the Authority of their affairs unless in his opinion overriding national interests so require.*" Mr. Crookshank added that most people would assume from these words that the Lord President would not interfere with the day-to-day detail.

Mr. Crookshank ended his speech with a reference to radioactive cobalt in cancer therapy. He stated that small radium units at University College Hospital, Leeds and Sheffield have been converted into radio-cobalt units. He then mentioned the great Canadian radio-cobalt bomb presented last year to the British Empire Cancer Campaign, and said that, by a strange coincidence, that very morning (March 1) the first patient was treated with that bomb at the Mount Vernon Hospital.

Somewhat surprisingly, atomic energy development was treated in the House of Commons as a political issue, the Labour Party seeking to delay the passage of the bill by a token period of six months. The upshot was a division, and the Government carried the day by 244 votes to 226. The voting followed the party lines.

The large-scale development of atomic materials has been described in the recent official publication entitled *Britain's Atomic Factories.* Until this booklet appeared our atomic factories were treated as very hush-hush installations. The secrecy which was so rigidly enforced in the case of Capenhurst (the U235 factory) and Windscale (the plutonium factory) was both understandable and desirable, for both plants manufacture atomic explosives. Risley, the design headquarters where the detailed plans were prepared for the equipment of Capenhurst and Windscale, also had to be treated as a top-secret unit.

All the factories dealt with in the official booklet were set up by the Ministry of Supply, which was given responsibility for atomic energy development by the Atomic Energy Act of 1946. In other words, the production of fissile materials was made the concern of the same ministry which looks after government production of conventional explosives (with the one exception of the explosives which the Navy manufactures in its own factories). The new Royal Ordnance Factories which were set up to meet the Services' increased demand for

The Springfields Atomic Factory where uranium is extracted from the imported ores. FIG. 1 (*left*). This picture shows a cyclone separator on top of an ore crusher. The ore is crushed into small pieces, and the separator is essential to prevent the radioactive dust produced in the process from escaping into the factory or into the outside atmosphere. FIG. 2 (*right*). The crushed ore is dissolved in an acid bath.
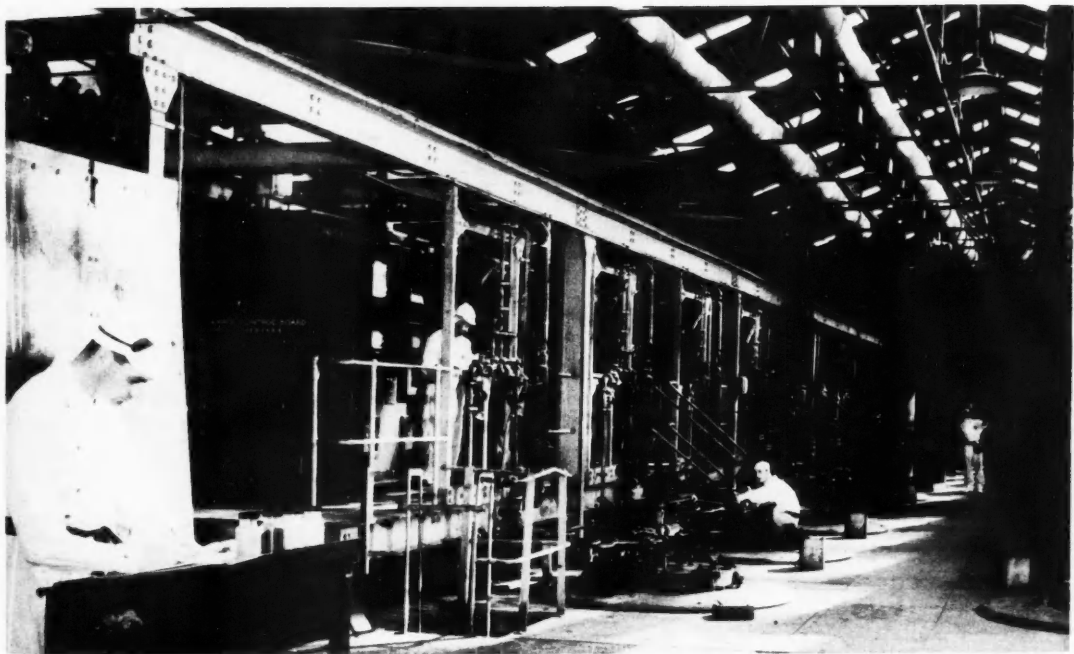
FIG. 3. The furnace section of the 'Dryway' plant of the Springfields Factory. This section converts pure ammonium diuranate to metallic uranium. The diuranate is converted to the metal in two stages; in the first it is converted to pure uranium tetrafluoride by heating the powder in electric furnaces, reducing it, and then passing over hydrogen fluoride gas at the appropriate temperature; the hydrogen fluoride reacts with the diuranate to form solid uranium tetrafluoride. This is the Dryway process. This fluoride is then removed from the furnace, mixed with chips of calcium metal in a mould, and fired, resulting in its reduction to metal.

explosives in the last war were built by the Ministry of Supply using the engineers and designers of the Ministry of Works, and of Woolwich Arsenal and Waltham Abbey Royal Gunpowder Factory.* The civil engineering side of the new sites was a Ministry of Works responsibility. The designing of the chemical plant for these R.O.Fs. was done by experts of Woolwich Arsenal (who concentrated on TNT and RDX manufacture) and of Waltham Abbey (who looked after cordite and picrite), the Propellent Planning Department coming in as the responsible co-ordinating agency.

When these explosives factories were ready to go into production, they were staffed with civil servants belonging to the pre-war explosives manufacturing service reinforced with scientists borrowed from I.C.I., from other industrial firms and from elsewhere.

After the war there was a general scramble back to industry, and only a few men stayed behind to wind up the now redundant explosives factories.

When the Ministry of Supply took the decision to establish atomic plants after the war, it adopted a method of achieving this end which was quite different from the one which the Americans had employed with great success. In Britain there was only one firm which might have been given contracts for running atomic plants, namely I.C.I. The American government on the other hand had been able to turn to a number of chemical firms (including du Pont, Monsanto, Carbon and Carbon Chemicals Corporation) and to such organisations as the M. W. Kellogg Company which specialise in design and construction of new plants, and the industrial-scale atomic plants were designed, built and operated by these firms. The British course with regard to the production of atomic explosives was in effect a continuation of the old policy of government factories run by civil servants. A construction organisation was built up; design was organised by the special unit at Risley, whose key men were recruited from among Ministry of Supply experts on explosives production and from I.C.I. engineers. Civil engineering work was left to the Ministry of Works. The actual operation of the atomic factories has depended on a small nucleus of old explosives works managers, and Britain's successes in the atomic production field are largely due to the tremendous exertions of these men. Typical of these energetic experts to whom the country owes so much are S. F. Hines, H. G. Davey and Dr. H. Rogan. Hines, who used to run Springfield and now runs Capenhurst, was in charge of the TNT factories at Pembrey and Sellafield, having been a pre-war civil service explosives expert at Waltham Abbey. Mr. Davey was before the war a lecturer in chemical engineering at the Treforest School of Mines; the war took him to the TNT works at Pembrey, and thence to Drigg and Sellafield. Dr. Rogan, now works manager of Springfields, was a

* Waltham Abbey's powder-mills go back to the days of Queen Elizabeth the First, when powder-making became a royal monopoly; presumably the hornbeams of Epping Forest were the source of charcoal for the gunpowder made at Waltham Abbey.

chemist with the Nobel Division of I.C.I. at Ardeer before joining the R.O.F. organisation at Pembrey, where he worked throughout the war. It was Britain's great good fortune to have such a nucleus of men who knew each other well and who also knew, in the case of the Windscale Works, the men who were to become the rank and file of that atomic factory.

The new factors which arose because ordinary chemical production differs in many respects from the large-scale preparation of fissile materials impinged with particular force upon the plant designers, and here if credit is due to any single individual it is to Sir Christopher Hinton. He was an I.C.I. engineer at Ardeer before he took charge of the government explosives filling factories, and he was running these plants down to peacetime level when he was chosen for his new job in the atomic production field. The production side of the Atomic Energy Authority's activities will, of course, continue to be his responsibility.

Britain's Atomic Factories contains some technical information of unusual interest. The chemical side of atomic production is most important, and here several of the techniques which have been perfected are rather novel. Whether one is interested in preparing U235 or plutonium, high purity is required in the uranium compound upon which the gaseous diffusion process depends and in the uranium which goes into the piles that synthesise plutonium. One of the big advances in this connexion was made by a scientist of the U.S. National Bureau of Standards, J. I. Hoffman, who discovered how to remove all the impurities from uranyl nitrate by solvent extraction (using ether). The know-how of this technique was apparently not given to Britain by the U.S.A. and therefore a research unit at Harwell had to put in a major effort on the fundamental problems involved in the purification of uranyl nitrate by solvent extraction.

Handling of plutonium-enriched rods from the pile is cunningly contrived and takes place under twelve feet of water, which provides an effective radiation barrier that is *optically transparent* and therefore presents no difficulty when the operators need to shift the rods, this being done of course by manipulation with special tools actuated at a safe distance from the radioactive material.

Plutonium separation also involves a solvent extraction process. The plant upon which plutonium extraction depends is quite small by ordinary chemical industry standards. The smallness of scale is a great advantage so far as one problem is concerned; for obvious reasons the stainless steel welds in the plant have to be first-class, and inspection of these welds is rendered very much simpler by reason of the relative smallness of each weld. The final extraction process is concerned with really small quantities of material, which can be handled in small scale Pyrex plant similar to that used in the preparation of fine chemicals.

The gaseous diffusion process for concentrating U235 seems no less fantastic today than it did when we first read about it in the Smyth Report of 1945. It can still be said that the complexity of this multi-stage process

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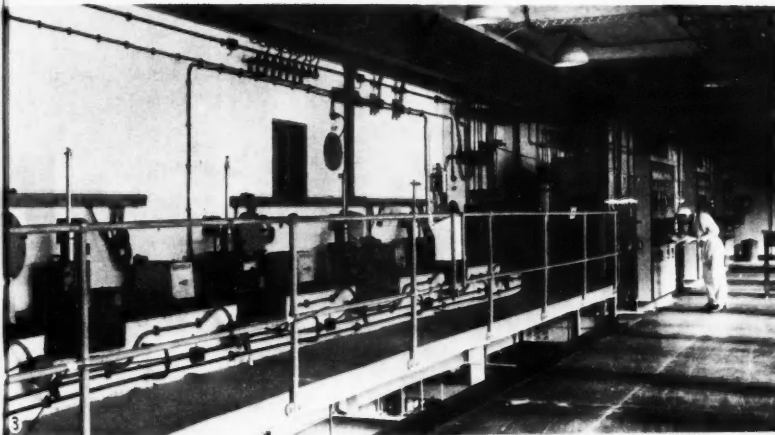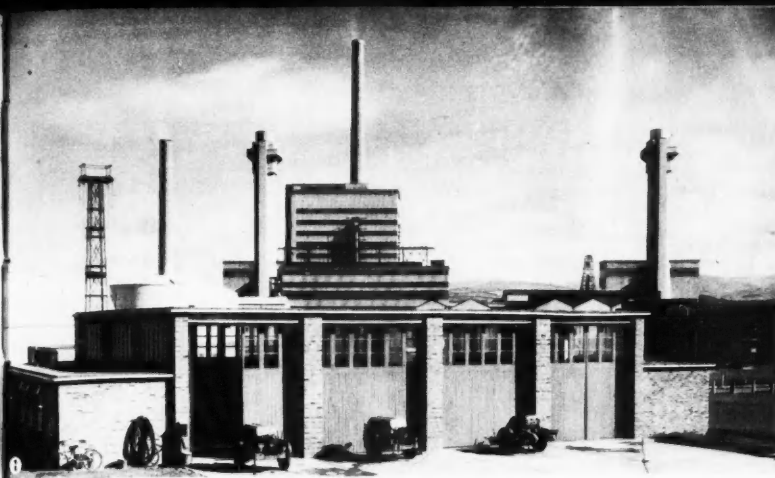
FIGS. 1–5. *The Windscale Factory at Sellafield.* 1. *General view of the works. The stacks of two plutonium-producing piles (each with a filter near the top) are visible, and between them can be seen the plutonium-extraction plant with its high stack.* 2. *One pile with its 400-ft. high chimney, at the top of which is the filter that takes out the last traces of radioactive matter from the air that cools the pile.* 3. *A view inside the plutonium-extraction plant.* 4. *Pipelines carry medium-active effluent after treatment for discharge into the sea.* 5. *H. G. DAVEY, Works General Manager at Sellafield.*

FIGS. 6–7. *The Capenhurst U235 factory.* 6. *A main corridor between two rows of gaseous-diffusion cells.* 7. *White-clad process workers operate controls on the steel deck above the cells, which are each the size of a dwelling-house.*

under high vacuum is not equalled in any branch of the chemical industry. Particularly interesting is the method of removing the hexafluoride of U235 by a discontinuous freeze-trap.

When one reads *Britain's Atomic Factories* one cannot help wondering about certain long-term problems such as the disposal of radioactive effluents from atomic plants. The American view is that this problem is as far from satisfactory solution as it ever was.

An operating atomic plant is a constant source of worry in case something should go wrong. The only policy which seems to be in force in the U.S.A. is to whip out the defective part and build a radiation-proof shelter round it. Some of the older atomic plants in America are supposed to be chock-a-block with defective units which have been shed and shielded in this way. Something like this seems to have happened at Chalk River where somebody pulled out the control rods instead of dropping them in: it took about two years to clear up the mess which that inadvertent accident caused. The Minister of Works talks of a 'Dome of Discovery' to act as a shield for the Dounreay pile in the very remote prospect of a slight leakage of radio-activity should there be a failure in certain parts of the plant. It is good to know that all possible precautions will be taken at Dounreay, for it was stated in Parliament by Sir David Eccles that "the local authorities have been consulted and with their help arrangements will be made as to what should be done in this most unlikely event." Doubtless no effort will be spared to render the automatic control of this fast-neutron pile as perfect as possible but the Chalk River incident indicates that atomic piles are a long way from being fool-proof and that when things do go wrong the radiation hazards are very serious indeed.

SMOKING AND CANCER

The Minister of Health's statement about smoking and cancer of the lung has certainly scared the public, and it needs to be said without more ado that the connexion between the two things is by no means as clear as medical statisticians like to make out.* No carcinogen responsible for lung cancers has yet been isolated. A fact which puzzles us is why, when the Minister was asked for figures for the relative incidence of lung cancer in light, heavy and non-smokers, none could be made available.

The Minister's statement was rather alarming and it should be noted that the phraseology he used was not quite exact. There seems to be some statistical correlation between the increase in the amount of lung cancer and tobacco consumption; on the other hand, as one scientist pointed out to us, it would probably be possible to find a similar kind of correlation between figures for lung cancer and the number of newspapers that are read. This point was not made flippantly but to stress the fact that a statistical correlation may have nothing to do with a causal connexion. The truth is that science knows

* This remark also applies to the B.B.C. feature on Smoking, which was broadcast on March 12.

virtually nothing about the effect that tobacco smoke has on the lungs. Certain tars derived from tobacco smoke have produced *skin* cancers in mice, but this proves very little; for it is not known how these substances affect the lungs, nor is it known whether smokers inhale them in sufficient quantities to cause any upset.

All the cancer experts are prepared to say at the present time is that there seems to be a *prima facie* case for investigating the cause of lung cancers, and considering what connexion, if any, smoking may have with it. These same experts are actually much more disturbed about the possible effects of atmospheric pollution in this context, and it has just been suggested that the soot of cities and industrial areas coupled with the inhalation of tobacco smoke may have an effect more powerful on the human body than either soot or tobacco smoke taken into the lungs separately.

Tobacco smoking has, of course, been under heavy fire ever since it was introduced to Europe in the 16th century. It was anathema to James I, and in some countries it was declared a capital offence. The canton of Bern included "Thou shalt not smoke" among its ten commandments. From time to time medical men have come forward with alarmist claims about the damage which various constituents of tobacco smoke are supposed to have on human beings. These claims have never stood up to careful investigation, being based on fancy, not on fact, though there is no denying the bad effects that excessive smoking can cause.

There is in fact nothing more to be said on this issue until the medical research workers have completed the new programmes of investigation they are embarking upon. Until that time, the attitude of the smoker is likely to remain much the same as ever. When the effect of the Minister's scare has worn off, he will go on smoking as hard as ever and say to himself:

> Tobacco is a dirty weed. *I like it.*
> It satisfies no normal need. *I like it.*
> It makes you thin, it makes you lean,
> It takes the hair right off your bean.
> It's the worst darn stuff I've ever seen.
> *I like it.*

THE OLDEST LIFE

Palaeontologists periodically get a pleasant shock when they discover fossil remains of some plant or animal which one would not expect to find preserved at all. A classic example was provided by the discovery of well-preserved traces of jelly-fishes. The latest find in this category is reported from Canada, where two scientists—Prof. Elso S. Barghoorn of Harvard, and Prof. Stanley A. Tyler of Wisconsin University—have discovered two kinds of fungi, two of algae, and an organism which they believe to be a calcareous flagellate. These amazing fossils were found in a deposit of chert lying below an iron ore bed on the northern shore of Lake Superior, near Schreiber, Ontario. The age of the iron ore bed is estimated by Prof. Patrick Hurley of M.I.T. as 1300 million years, and the date suggested for the fossils

The Canadian fossil plants which are estimated to be 2000 million years old. They were found in chert occurring in the Keewatin rocks of the Canadian Shield near Schreiber, Ontario. (*Left*) One of the fossil fungi. The arrow points to a fungus spore which seems to be attached to a long filament or *hypha*. Magnification is about 1000 times. (*Right*) One of the two fossilised algae. Algal filaments make up the black mass visible in the centre; the rest of the structure probably corresponds to a gelatinous sheath.

extracted from the chert is about 2000 million years. This is of course a far greater age than that estimated for nearly all fossils previously discovered.

Of particular interest are the two fossil fungi, for relatively few good fossils have been obtained for this group of plants. The odds are heavily against such discoveries, for fossil fungi would be found associated with other plant material, and the circumstances would not favour the recognition of the fungi present. This will be obvious if the reader will visualise a mixture of plant remains comparable to garden rubbish or peat being preserved, and then think of the difficulty of identifying fossil fungi in the conglomeration of mineralised matter which has survived after 2000 million years.

Prior to the new Canadian discovery, knowledge of fossil fungi has come from chert deposits, notably the Rhynie Chert (Kidston and Lang, *Trans. Roy. Soc.*, *Edinburgh*, Vol. 52, 1921, p. 855) and from coal balls (several authors: *see* Pia, in Hermer's *Handbuch der Paläobotanik*, Munich, 1927). The fossil fungi just cited were well preserved. All of them were fungi belonging to the lower fungi (reliable records of higher fungi begin

in the Cretaceous). Some of the fungi from the Devonian and Carboniferous rocks may have been simple agents of rotting, others were almost certainly parasites, and most, perhaps, were mycorrhizal. Butler (*Trans. Brit. Mycological Society*, Vol. 22, 1939, p. 284) stresses the likeness of the fungi found by Kidston and Lang to a widespread group of mycorrhizal fungi which exist at the present day.

Though there are numerous records of fossil fungi, often accompanied by careful descriptions of the material, our knowledge of these plants remains fragmentary. Mycologists have been so occupied with urgent work on the living fungi, especially with those which are important for industrial and kindred reasons, that they have had little time or inclination to turn to the fossil forms.

The discovery by the two American workers of fossil fungi from very ancient rocks in Ontario is of great interest. If the rocks are as old as they are said to be, then this material is very much older than the fungi from the Devonian and Carboniferous rocks, and the find suggests, therefore, that the fungi must rank among the oldest of organisms. The fungus shown in their

photograph has a general resemblance to those found in the Rhynie Chert, though the structure interpreted as a spore seems rather small; this, however, may merely be a matter of immaturity of the specimen at the time when it was fossilised. It is to be hoped that more specimens will be found, and that detailed descriptions and illustrations of the finds will soon become available.

We understand from Prof. Arthur Holmes of Edinburgh University that these Canadian rocks are indeed as ancient as Prof. Hurley of M.I.T. has suggested. The oldest of this series of Canadian rocks is probably 2500 million years old. Prof. Holmes informs us that the oldest authenticated plant remains are algae from chert and pillow lavas known as the Bulawayan System in S. Africa. These were discovered by Dr. A. M. Macgregor (A pre-Cambrian algal limestone in Southern Rhodesia, *Trans. Geol. Soc., South Africa*, vol. 43, 1940, pp. 9–15). He found algal structures in limestone associated with chert and pillow lavas belonging to the Bulawayan System. Radioactive minerals in pegmatites which cut these rocks are the oldest yet accurately dated. Their age is certainly over 2600 million years. It is Prof. Holmes's opinion that life has flourished on the earth for at least 2700 million years.

FOUR CENTURIES OF TULIPS

Four hundred springs ago the first tulip bulbs ever planted in Europe came into flower in an Austrian garden. They had been sent to Vienna by A. G. Busbequius, ambassador of the Austrian Emperor Ferdinand I to Suleiman the Magnificent of Turkey. How he came across the tulip is described in a letter, which is quoted from *The Turkish Letters of Ogier Ghiselin de Busbecq* (1689):

> Having delayed at Adrianople one day we were going on towards Constantinople, now near, for we were almost accomplishing the end of our journey, and as we were passing through the district an abundance of flowers was everywhere offered to us—narcissus, hyacinths, and those which the Turks call *tulipam*, much to our wonderment, because of the time of year, it being almost the middle of winter, so unfriendly to flowers. Greece abounds in narcissus and hyacinths remarkable for their fragrance. Scent in tulips is either wanting or very slight; they are cultivated for the variety and beauty of their colours.

This is the first clear-cut reference to the tulip in European literature, and it appears to be the origin of the name *tulip* itself. A search of early Persian and Turkish literature has revealed references to this flower, but in all of them (e.g. Omar Khayyám's poems) it is called *laté*. *Tulip* is thought to be a corruption of *tulbend*, a Turkish word meaning *turban*; Sir Daniel Hall suggested that the name which Busbequius gave the flower in his letter arose through a misapprehension— quite possibly those who gave him the flower pointed out its resemblance to a turban (the simile would be very apt for any tulip similar to such a variety as Keizerskroon) and Busbequius was misled into thinking that the word *tulbend* was the proper Turkish name for this flower.

The tulip soon became famous all over Europe. The Swiss botanist Conrad Gesner saw it growing in a garden in Augsburg in 1559, and the picture of this plant which he published in his *De Hortis Germaniae cum Descriptione Tulipae Turcarum* (1561) is the earliest known European illustration of a tulip. Gesner tells us that the plant was "growing with a single, large, reddish flower, like a red lily, with a pleasant smell, soothing and delicate, which soon leaves it".

This type of tulip is appropriately known as a Gesnerian tulip. Its exact geographical origin is quite unsettled, and Sir Daniel Hall never went further than to say "its early mention in Persian literature as a garden flower seems to indicate a Persian origin, though in Persia itself Gesnerian tulips are less frequent than in Asia Minor and the Trans-Caucasus". It has proved impossible to find a wild species that can be identified as the ancestor of the modern tulip, which is not at all surprising, for when Busbequius discovered the plant "it was then a 'made' flower, evidently with a long period of cultivation behind it, for among the Turks it existed in numerous varieties possessing every character, except perhaps the 'parrot' form, with which we are familiar today. Descriptions in the early herbals and representations in Dutch pictures of the 17th century display a wide range of colours and both short cupped and long pointed flowers, the latter of which seem to have been most esteemed in Turkey. Broken forms were already common and most prized". Gesner's name is immortalised in the name *Tulipa gesneriana*, a Linnean species with crimson-scarlet flowers which is found in Asia Minor and elsewhere.

This species, with another half-dozen related species comprise what is known as the Gesnerian group of tulips. It must be emphasised that it is not possible to point to any one of these seven species and say definitely that it is the species from which the garden tulips derived. For there is a possibility that more than one species was involved in the origin of the cultivated tulips.

The pigmentation of tulips is an important consideration in all attempts to track down the original ancestor

An early illustration of a tulip (from Mattioli, 1565, *Commentarii*, p. 1244).

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(*Left*) The classic picture of 'broken' tulips from R. Thornton's *Temple of Flora* (1799–1807). (*Right*)
The oldest variety of tulip still in cultivation is Zomerschoon which dates back to 1620 at least.

of the cultivated flower, and here the biochemists have done a great deal of work which geneticists have to take into account in their researches. Two main types of pigment are involved. On the one hand, there is a white or yellow 'ground colour', and this is contained in plastids—the coloured granules which one finds in the interior of the petals. These plastids account for all the colour of the white tulips and the yellow tulips.

But in tulips of all other colours there is a second source of pigmentation. This is a pigment belonging to the anthocyanin group and it occurs dissolved in the sap that fills the cells of the petal's cuticle. The anthocyanin pigment provides a range of crimson and purple shades. You can check this fact for yourself quite easily. If you strip the cuticle from a tulip petal, you can see that the crimson or purple component of the flower colour belongs to the cuticle, and the white or yellow 'ground colour' resides in the rest of the petal.

In a particular species of wild tulip (e.g. *Tulipa eichleri*, *T. fosteriana*) only one kind of anthocyanin is present. For example, in the two species just mentioned, the anthocyanin is pelargonidin glucoside, a pigment which is also found in the garden pelargoniums (more commonly called 'geraniums' by laymen). Another anthocyanin found in the species tulips is delphinidin, the pigment of

the delphinium. The history of the garden tulips has involved a tremendous amount of cross-breeding and the occurrence of many hundreds of mutations. The result is that the biochemists now have a very complex picture to unravel when they start investigating the rich range of pigmentation associated with the modern varieties of tulips. It has about the same degree of complexity as the range of colours presented by the famous Russell lupins, which represent an equally complex problem to the geneticists as do the tulips.

The exact shade of colour which arises in an individual plant from the presence of a particular anthocyanin depends on a number of factors. The intensity of colour will obviously depend on the concentration of pigment, but this will also be affected by the ratio of cells containing coloured sap and those containing no pigment. A variation in the pH of the cell sap will also affect the issue; the anthocyanins are like litmus paper, so that an acid sap gives a reddish shade in contrast to a bluish shade which goes with a less acid sap.

Another factor which affects the colour of tulip flowers is the presence of certain viruses. The 'broken tulip', in which the petals are variegated, is in fact an example of a virus disease, though it should be realised that not every variegated tulip owes its bizarre appearance to a

(*Left*) A 'broken' Cottage tulip of the variety called Perseus. The darker zones are orangy-red, and the rest is yellow. (Picture by Prof. E. van Slogteren of the Laboratory for Flowerbulb Research at Lisse.) (*Centre*) Breeding work is being done on tulips other than the ordinary Gesnerian type. This photograph shows new hybrids of the species tulip *T. fosteriana*, which has a rich crimson flower. (*Amateur Gardening* photo.) (*Right*) Parrot tulips are nearly as old as broken tulips. This is the yellow variety called Sunshine. (*Amateur Gardening* photo.)

virus. (Some variegation is due to the occurrence of chimeras; see DISCOVERY, "Plant Chimeras," Sept. 1953, pp. 268–9.) Readers will find a very interesting passage dealing with viruses that cause 'broken tulips' in the latest New Naturalist monograph, *Mumps, Measles and Mosaics* by Kenneth M. Smith and Roy Markham (London, Collins, 1954; 160 pp., 18s). This kind of tulip figured in many paintings of Rembrandt's day,* and one woodcut from about 1622 shows the phenomenon quite clearly. There is a reference to 'broken tulips' in an account by Carolus Clusius dated 1576. As the New Naturalist book says, we may therefore regard 'tulip break' as the oldest virus disease known. It is quite possible to obtain a virus-free strain of a 'broken tulip', and then synthesise the 'broken' form by inoculating it with virus; for example one can take the rich mauve variety called *Mary Stuart*, and then 'break' it with virus when one gets an attractive combination of diseased zones (which are yellow in colour) on a mauve background. The Dutch have done much research on these virus effects. It seems from their investigations that the tulip is incapable of producing antigens to counteract the effect of the viruses. Almost certainly these viruses are transmitted by aphids, for the number of 'broken tulips' increases under conditions that favour the increase of the aphids. When these viruses are injected into animals such as rabbits and horses antibodies are generated, which are capable of neutralising the pathogens if the horse- or rabbit-serum is introduced into an infected

* Appropriately, one of the best varieties of 'broken tulip' is called *Rembrandt*; this has reddish markings on a white ground.

tulip. A major centre of tulip-virus research in Holland is Lisse, where a laboratory under Prof. van Slogteren is making many interesting discoveries.

This is not the occasion to expatiate on the history of tulip cultivation or upon the crazy speculation in tulip bulbs which occurred in Holland between the years 1634 and 1637—the 'tulipomania', as it was called, that rivalled England's 'South Sea Bubble'. Any reader who is interested should consult *Tulipomania* by Wilfrid Blunt, a King Penguin book published in 1950. Scientifically two of the most important books are *The Genus Tulipa* (Royal Horticultural Society, 1940) and *The Book of the Tulip* (Martin Hopkinson, 1929), both of which were written by Sir Daniel Hall while he was director of John Innes Horticultural Institution.

SILICONES

About ten years ago commercial production of silicones began—in the U.S.A.—and these materials are now available in commercial quantities in Britain.

In the early days the two items in the silicone range which gained the most publicity were 'bouncing putty' and silicone waterproofing agents. The former was a real oddity, having a combination of paradoxically different physical properties. When a lump of 'bouncing putty' is dropped, it bounces like rubber; if it is squeezed, it deforms like putty. Left to its own devices, it behaves like pitch and proceeds to flow. When the scientists first announced its discovery no practical use was known for this material, and no real use has since been found for it. Schoolboys who frequent novelty joke shops are likely to have seen it sold under such names as 'Silly

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Putty'. (The producers of silicone compounds are still interested in the possibility of finding some use for 'bouncing putty', and any reader who has an inspiration in this direction will find a ready welcome for his ideas; it should however be noted that already suggested is a possible use in damping devices and in sealing and filling compounds, while 'bouncing putty' might also be exploited in physiotherapy as an exercise for crippled muscles).

The waterproofing property of certain silicones hit the headlines in 1944, as a direct result of a press conference organised by the General Electric Co. in America. Reporters who attended that conference were more than somewhat surprised when the press officer opened a packet of cigarettes, tipped the whole lot into a bowl of water, and then invited the pressmen to take a cigarette. They were astonished to find that this rough treatment had no effect whatsoever on the cigarettes, which emerged from the test perfectly dry, and perfectly smokable. The cigarettes had, of course been impregnated with a silicone, and today these water-proofing compounds are exploited in many ways: for instance, they are used to waterproof textiles (both heavy-purpose materials used in tents and awnings, and such things as nylon and Terylene), for dressing fishing lines, and for treating masonry and glassware.

The last-mentioned item is today well known. It is possible, for instance, to buy booklets of thin paper impregnated with dimethyl silicone fluid, and this paper is ideal for cleaning spectacle lenses. Biologists find this material very useful for cleaning microscope eyepieces. An alternative to the lens tissue is the straightforward application to the glass of a 1–4% solution of dimethyl silicone in isopropyl alcohol; this can be sprayed on to lens or mirror, or it can be wiped on with a cloth, and when the glass is polished the alcohol evaporates, the silicone deposit which remains behind provides a polished, slick surface that is waterproof and easily kept clean. These waterproof films are remarkably stable; they remain effective after baking, for example. The electrical industry exploits them too; electrical equipment (particularly radio and precision equipment) can be rendered perfectly waterproof, which means that variations in humidity will not produce changes in electrical resistivity.

A phial or test-tube which has been silicone-coated is a valuable item in micro-analytical work, for the very good reason that when one has to transfer a liquid from one such vessel to another drainage is practically complete (because the silicone film is water-repellant and the amount of liquid lost in the transfer is negligible). It is possible to take advantage of this same effect to get complete drainage from medicinal glassware such as penicillin phials. Silicone preparations are also being used to lubricate the glass barrels of hypodermic syringes which then become more efficient instruments for transferring liquids.

Thus silicone waxes, which give an ideal polish to car bodywork, for instance, are now popular on both sides of the Atlantic.

The few applications given above illustrate that the silicones have certainly ceased to be laboratory curiosities. A new book entitled *Silicones and Their Uses* by R. R. McGregor, devotes over twenty pages to listing the great variety of applications which various industries have found for different silicones.

This book provides a useful and compact guide to the chemistry, preparation and applications of silicones. The fundamental work on organo-silicon compounds was done not in the U.S.A. but in Britain. The great authority on this group of substances was Prof. F. S. Kipping of Nottingham University, who published 54 papers dealing with them in the period from 1899 until 1944. His interest was an academic and fundamental one and so uncompromisingly 'pure' that, "when shown some of the first commercial silicones, he could scarcely bring himself to take more than a passive interest in them. After all, they demonstrated little that was new about the *chemistry* of silicon, so why should they be of particular interest to him?" This anecdote is told in McGregor's book, which certainly does justice to the importance of Kipping's contributions to this field of research. The development of silicones owes a good deal to other fundamental research men, including Staudinger, whose work in the field of high-polymer chemistry was belatedly recognised by the award of the Nobel Prize for Chemistry in 1953.

Commercial development of silicones was largely prompted by an economic stimulus. Manufacturers of glass were concerned to see the rise of competition from transparent plastics of the Perspex type, and the major industrial research project in the silicone field began when the Corning Glass Works in America engaged an organic chemist, Dr. J. F. Hyde, to investigate the possibilities of a hybrid polymer which would combine the properties of organic polymers (plastics) and glass, which is an inorganic polymer. A very direct stimulus for this line of research derived from the fact that Corning had just developed glass fibres and required a material which could be used for impregnating glass-fibre textiles and which would have better heat-resistance than the ordinary bonding materials then available. Specifically the researches of Dr. Hyde turned towards resinous compounds that would be of use as a heat-stable dielectric in tapes made of glass fibre. The idea of insulating materials capable of withstanding high temperatures was something that interested electrical firms, and the General Electric laboratories in the U.S.A. became associated with the Corning investigations. In 1943 the Corning Glass Works and the Dow Chemical Company jointly financed the first factory to produce silicones, and three years afterwards the General Electric Company started up the second American silicone plant. Britain lagged somewhat behind America in this field, but today two British firms (I.C.I., and Midland Silicones, which is associated with Albright & Wilson) are in the business; I.C.I.'s Nobel Division is now building a special plant to produce silicones at Ardeer in Ayrshire.

The industrial production of silicones starts with silicon tetrachloride ($SiCl_4$), which is of course an

UNCONVENTIONAL POWER UNITS FOR ROAD VEHICLES

W. HAROLD JOHNSON, M.A., A.I.N.A.

By unconventional in the present context I mean not so much novel or untried as not in common use or differing from the engines that all motorists know. For brevity and simplicity we will refer to these common engines as petrol engines, which is indeed their usual name today, though I use it not unmindful of the fact that when I started driving rather more than forty years ago petrol was the registered trade name of one particular brand of motor spirit sold by Carless, Capell and Leonard and that no one else could or did use the name. Far from being novel or untried indeed, one of my unconventional power units is the oldest of all (steam) and another is but a special version of the petrol engine. Let us take this special version first, the air-cooled engine.

AIR-COOLING

Of course all engines of all road vehicles are in the ultimate air-cooled but almost universally the air does its cooling job through the intermediary of water. Why? Why have jackets round your engines which are difficult and costly to cast and radiators that like the jackets are liable to damage by frost and why have pumps to force the water through the jackets and radiators to keep the engine cool when your engine is a heat engine and the hotter it runs the better, within limits. Above all why have the water when your engine could run just as well and more efficiently without it—I mean of course if it is designed to do so; I do not mean that an engine designed for water-cooling will behave better if run on an empty cooling system.

One reason is undoubtedly that the mention of air-cooling naturally suggests to most people a motor-cycle banging its way along the road in a series of ear-splitting barks, so that if we are inclined to regard motor-cyclists much as we would a squad of uncontrolled machine-gunners they and the manufacturers of motor-cycles have only themselves to thank. Unfortunately much the same impression has been given by some air-cooled cars of the past where air-cooling has been adopted in the cause of cheapness rather than efficiency; bystanders have concluded, naturally if wrongly, that excessive noise has been due to the air-cooling rather than to use of two (often horizontally opposed) cylinders instead of four or six which would have afforded a better basis of comparison with the majority of water-cooled cars. It is a fact that enclosing the cylinders and especially the cylinder heads in a jacket containing water does have a considerable damping effect on noise, but it is also a fact that some air-cooled engines have been as quiet as some water-cooled; I have yet to hear it said that an air-cooled aircraft engine is *ipso facto* noisier than a water-cooled of about the same output.

Some readers will undoubtedly recall the American six-cylinder Franklin car which had a power unit of some 25 h.p. rating, conventional in all respects except that it had

no water. Each of the six cylinders had radiating fins, vertical instead of the horizontal usual in most air-cooled engines, and the group of six was encased in a cowling with an opening above each cylinder head. A fan incorporated in the engine flywheel, also enclosed in a cowling coupled to that of the cylinders, drew air down over each cylinder and maintained a very satisfactory even working temperature which was I believe—I am relying on memory —about 150°C, a very much better working temperature than about half this figure which is normal for a water-cooled engine.

From the point of view of driver and passengers it was impossible to distinguish any difference whatever in the behaviour of that car from the behaviour of any ordinary, contemporary, water-cooled car of similar power. The Franklin was just as silent and just as flexible and just as powerful and as for endurance what water-cooled car could in 1915 (or for that matter in 1955) have been driven 860 miles *on bottom gear* without an engine stop, as was a Franklin? For this performance, which was officially observed, second and top gear ratios were removed from the gear-box and the average speed from Walla Walla, Washington, to San Francisco was ten miles an hour! The route included desert crossing and mountain climbing and when any water-cooled car equals that performance may we all be told about it.

A properly designed air-cooled engine can be as durable as a water-cooled—most of the Franklins that I drove were several years old and they all 'ran like silk'—and owing to the higher working temperature their fuel efficiency— miles per gallon of petrol—should be higher, an asset accentuated by the lighter weight of the car due to the absence of water.

Why then are there no air-cooled cars today? Of course there are some but at home they mostly have motor-cycle type engines that are intended solely for racing—it would be difficult to think of more effective propaganda *against* the air-cooled car as a substitute for, say, an Austin A40 or a Jaguar. On the Continent air-cooling is being adopted for several economy cars, very few of which would appeal to the average British motorist, but there is also something else. One of our national dailies recently illustrated a station or utility 'bus for eight or ten passengers which was driven by a four-cylinder air-cooled engine Apparently it is to be imported on a commercial basis from Germany where the famous Volkswagen with its four-cylinder (1131 c.c.) horizontally opposed engine has done much towards putting air-cooling on the motoring map. Many B.A.O.R. owners of these cars speak quite enthusiastically about them and I can truthfully say I have never ridden in a quieter petrol car. All of which seems to indicate that it may be time for our manufacturers to be thinking about air-cooling—and who am I to say that they are not?

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Just in case it should occur to anyone that this is not an exhaustive survey of air-cooled cars, past, present and possibly future, and that I have omitted several, I may perhaps add that I have not forgotten such interesting vehicles as the horizontally opposed twin A.B.C. and Rover, the radial North-Lucas of which the engine was mounted horizontally—i.e. with the crankshaft vertical—immediately above the back axle; the Y-engined Cosmos; and the so-called oil-cooled Bradshaw made by the old Belsize Company of Manchester of which I owned one about thirty-three years ago.

THE DIESEL

It may seem extraordinary, in fact it is extraordinary, to be led from air-cooling to the diesel. Until recently the two principles seemed to represent the absolute extremes of internal combustion engine practice—the essentially heavy slow-running diesel and the essentially light high-speed air-cooled engine. But within the past few years there have come on to the market several air-cooled diesels, one pioneer being the German Krupps, before the last War, and another the English post-war 15 h.p. Enfield flat-twin introduced as a power unit for small marine craft where it has justified itself. If we are to have air-cooling in marine craft where the water supply is unlimited, is not this significant?

Incidentally this is not the first time that the name Enfield has been associated with air-cooling. At the first motor show after the First World War (1919) one of the most interesting exhibits was the Enfield-Allday car with a five-cylinder air-cooled radial (petrol) engine. Few more intriguing designs have been seen before or since, but the designer (his name was Reeves) was too much ahead of his time and in spite of a most pleasing behaviour on the road the car never attained really commercial production. Also incidentally, I have while writing these notes received information of an air-cooled multi-cylinder diesel engine of very novel design about to be produced for private cars. Details cannot yet be given beyond saying that the engine works on the opposed pistons principle.

So far one cannot pretend that the diesel engine is established for private cars but it is capturing the commercial vehicle market, including taxi-cabs, and demands attention for its possibilities with private cars. Let us look at some of its characteristics.

The engine was invented by Akroyd Stuart an Englishman in 1890 and was all but ignored until Dr. Diesel a German tried to improve it in 1893 and having failed reverted to Stuart's principles since when the engine has universally been known as the diesel! The essential principle is that the charge is ignited in the cylinder by the temperature of compression and by nothing else though in early types of the engine now called semi-diesel, external heat—e.g. by a blow-lamp—was applied to part of the cylinder head to give necessary assistance for the initial explosions. The compression process is compression of air only, into which fuel is forcibly injected at the moment of maximum compression and therefore maximum temperature, before ignition which occurs, or rather begins, immediately the fuel enters as a fine spray into the highly compressed and heated air.

Differences between the diesel and petrol engine thus become apparent. In the former there is no mixture of air and fuel before combustion; in the petrol engine mixture takes place in the carburettor and inlet passages before entry into the cylinder where ignition is initiated by an electric spark. Thus the diesel requires neither carburettor nor ignition apparatus (magneto or coil and distributor) and diesel protagonists are never tired of telling how their engine lacks the two chief sources of trouble with a petrol engine. Until pressed these protagonists often omit to mention that instead of carburettor and ignition apparatus the diesel has as a vital component what is probably the supreme example of the highest precision engineering in common use today—the pump that forces and measures the liquid fuel into the cylinder (against the compressed air awaiting it) through an injector nozzle comprising one or more microscopic holes.

The sole means of controlling the power output of a high-speed diesel engine is by variation of the amount of fuel injected, which at full throttle on an engine of about 100 h.p. is about the size of a small grain of wheat for each cylinder of a four-cylinder unit. This variation is achieved by variation of the stroke of the four small pumps, each of which supplies one cylinder; any inequality in amount of fuel supplied means unevenness of running which can ill be afforded in an engine not normally noted for smoothness.

The pistons of these fuel pumps have no rings; they are a perfect fit in their cylinder bores, so perfect indeed that they are matched to their cylinders by selective assembly in manufacture and there is no question of interchangeability among the pistons. All this means money and the pump unit of a very ordinary four-cylinder diesel of say 50–60 h.p. may represent more than 10% of the total cost of the engine. It is true that the injection equipment is not troubled by the condensation that may put ordinary ignition equipment out of action but magnetos and sparking plugs do not suffer from carbonisation of injector nozzles which may also be choked by a microscopic speck of dirt. Maybe diesel injection gives less frequent trouble than petrol ignition but when trouble does come it may well be much more difficult to overcome and certainly more costly if new parts are required.

The compression ratio of a modern petrol engine ranges from 6 to 7·5 to 1; of a diesel it ranges between 12 and 20 to 1. This means that, throughout, the diesel must be a more robust and therefore a heavier job than the other, power for power, which in turn increases its manufacturing cost—two factors that have checked its possible application to private cars. But also resulting from the higher compression ratio the diesel has a higher overall efficiency, something like 40% as compared with the 25% of an ordinary petrol engine. Both engines show their best fuel consumption figures when running at or near full throttle which the engines of private cars very seldom do. Hence one reason why the heavy lorry or bus (or, rather, coach) with its engine consistently pulling hard will give a ton mileage of over 50 to the gallon of petrol as compared with about half that figure for a normally driven private car.

To elaborate this important point, a petrol car driven at say 60 m.p.h. may show a fuel consumption of 0·6 pint per brake horse-power hour; at 10 m.p.h. the consumption

per b.h.p. hour might well be doubled; for a diesel engine the corresponding figures would be nearly halved. These figures must of course not be confused with miles per gallon; a car that did 25 miles per gallon at 50 m.p.h. might well do 50 miles per gallon at 15 m.p.h. The practical aspect is that with a private car travelling at constantly and widely varying speeds—i.e. engine loading—the advantage of the diesel engine might be less marked than it would with a vehicle—e.g. a lorry and still more a boat—of which the engine was normally working much nearer to its maximum power output.

It is often urged in favour of the diesel that its fuel costs less than petrol which is true but not quite so true as is sometimes thought. A recent inquiry brought a quotation of 4s. 1d. for diesel oil as compared with 4s. 6d. for the best and 4s. 2d. for the cheapest petrol, per gallon in all cases. If purchases are made in bulk (by the ton) the discrepancy in favour of diesel oil is greater; but how many private car owners would buy their fuel by the ton?

The essential robustness and therefore weight of the diesel engine as compared with the petrol engine, power for power, has already been mentioned and robustness naturally suggests durability. But let it not be forgotten that the robustness when needed to take extra stresses may not mean a greater safety or wearing factor and it certainly does not mean easier or less costly maintenance any more than it indicates any gain in smoothness or silence of operation. The diesel knock is characteristic, contrary as this seems to the 'continuous burning' as the diesel explosion is sometimes described in contrast to the more explosive burning of the petrol. Readers who wish to pursue this matter further will find it fully treated in the third edition of Sir Harry Ricardo's *The High Speed Internal Combustion Engine*, revised by H. S. Glyde, where the two-phase nature of the petrol explosion and the three phases of the diesel are expounded—note that these are phases of the explosion or burning and have nothing to do with the cycle or strokes of the engine.

Bearing in mind all the various factors I just cannot develop any real enthusiasm for the diesel as a power unit for light road vehicles and my scepticism was increased by an exhibit at the last Earl's Court Show. The only diesel-engined car was the Borgward which had a four-cylinder engine, bore and stroke 78 by 92 mm. giving 1758 c.c. capacity and a claimed power output of 42 b.h.p. at 3400 r.p.m. with a compression ratio of 19·8 to 1—very near the practical limit. On the same stand was a four-cylinder petrol-engined car *with the same bore and stroke* but giving a b.h.p. of 60 with a compression ratio of 6·35 to 1! Why treble your compression ratio to lose your horses? Also on

the same stand was another car with a petrol engine of 1498 c.c. to give 80 b.h.p. with a compression ratio of 8·5 to 1 which incidentally is above Sir Harry Ricardo's practical limit for petrol engines. He points out that ratios between 8 and 12 to 1 are practically unusable; anything over 7·5 to 1 in a petrol engine demands specially doped fuel to prevent pre-ignition, anything under 12 to 1 in a diesel engine requires extraneous aids—e.g. externally applied heat—to cause ignition. Nevertheless here we have at Earl's Court a German petrol car with a compression ratio of 8·5 to 1 and not a word said about special fuels; we know about the motor-cycle dirt track engines with compressions well into the diesel sphere, and their special fuels. There are of course many indications that Continental manufacturers are pressing faster with diesel engines for private cars than English or American. But the announcement of a Vanguard with a diesel instead of a petrol engine is a very significant move by the Standard Company, of Coventry. The new car with its two-litre engine (same capacity as the petrol unit) is to cost about £200 more than the ordinary Vanguard and is expected to save £125 in fuel costs over a mileage of 20,000.

It is not only fair, it is necessary to add that one diesel engine manufacturer, Messrs. F. Perkins Ltd. of Peterborough have supplied four-cylinder engines with a bore and stroke of 3½ by 5 in., giving a b.h.p. of 43 at 3000 r.p.m. for use in London taxi cabs. This engine is made to replace existing Austin petrol units and is coupled up to the existing clutch and gear-box. The cost of the replacement unit is £280 and the cost of its installation is covered, it is claimed, by the sale of the petrol unit. The results of actual tests show an average decrease in fuel consumption from 17 m.p.g. with petrol to 30 and in some cases 34 m.p.g. on diesel oil, and on an annual mileage of 48,000 miles—say approximately 1000 per week, allowing for periods when the vehicle might be out of action—there is a claimed total saving in running costs averaging £5 per week.

This is of course very encouraging, but there never has been any doubt as to the economy of the diesel unit over the petrol in certain types of vehicles. The saving with heavier vehicles—i.e. coaches and lorries—is even more marked.

STEAM

It seems strange, it *is* strange, to talk of the oldest of all power units for road vehicles as unconventional, but there it is and steam seems to have been driven from our roads for ever. In writing about it I must try to prevent my enthusiasm from running away with my judgment, but no one who has had any experience of a modern steam car—which means a steam car of about thirty years ago—will ever forget it or want to forget it. We talk of silent, smooth and lively petrol cars but the terms are merely relative and mean that those cars are in those respects better than some others; for an absolute meaning to those terms we must turn to steam.

Thirty-odd years ago I used to conduct extended tests on thirty or forty cars a year and I used to describe some of them as silent, smooth or lively; very occasionally I could and did say all three things about one car but it was not until I had used a Stanley Steamer that I really knew what

FIG. 1. Sketch of the first car to exceed two miles a minute—the Stanley Steamer, which achieved 127 m.p.h. in 1907. This must have been one of the first attempts at streamlining a car for speed purposes.

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FIG. 2. A SECTION THROUGH THE VOLKS-
WAGEN 4-CYLINDER AIR-COOLED ENGINE
showing the arrangement of the hori-
zontally opposed cylinders in two pairs
on each side of the horizontal crankshaft.

1. Crankshaft   7. Rocker arm
2. Flywheel   8. Rocker arm shaft
3. Connecting rod   9. Valve
4. Piston   10. Valve Spring
5. Cylinder   11. Fuel pump
6. Cylinder head

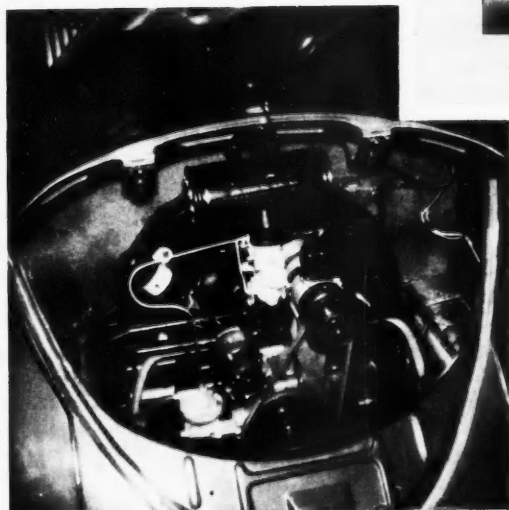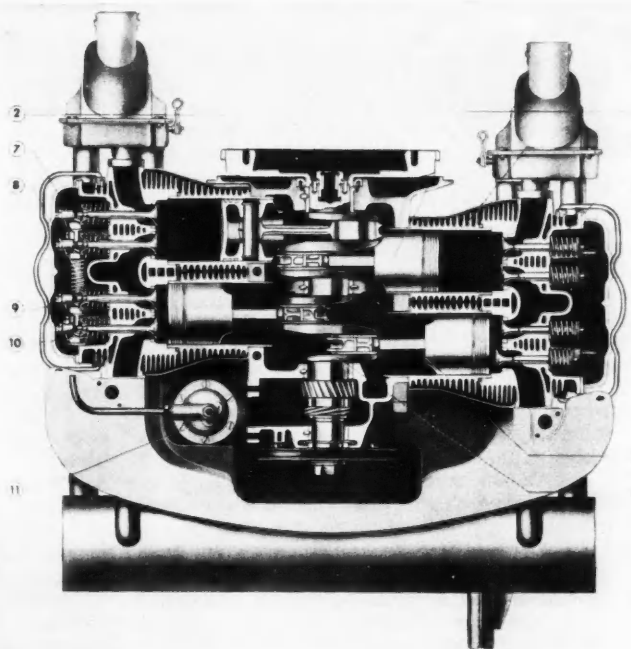FIG. 3. The Volkswagen 4-cylinder air-cooled
power unit mounted in the 'boot' at the rear of the
car. The cylinders can just be seen; the dynamo
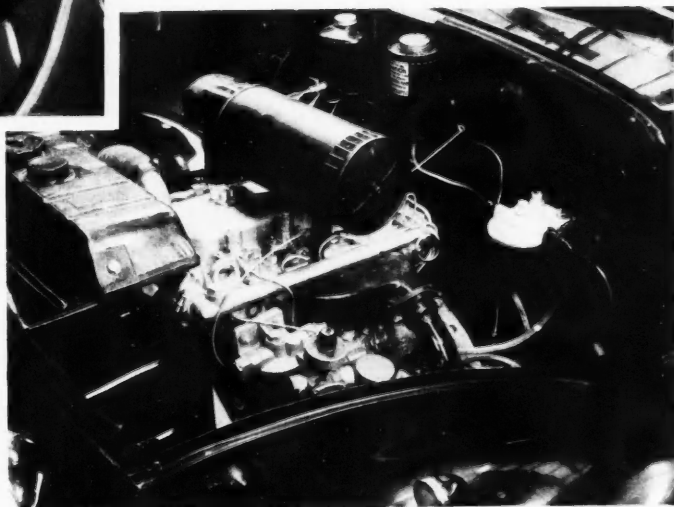and carburettor with air cleaner are clearly shown.

FIG. 4. A Perkins diesel engine installed
in a London taxi-cab to replace the petrol
unit. The photograph shows two of the
injector nozzles leading into the cylinders
and part of the fuel pump, under the
exhaust pipe.

the words could mean. Some of those petrol cars were both lively and fast—remember the 30/98 Vauxhall and the various sports Sunbeams?—but there wasn't one to which a steamer could not have offered a tow-rope after a couple of hundred yards' running from a level start, though admittedly the tow-rope would have become slack after about a quarter of a mile. That was the trouble, or one of the troubles, about the steamer—it just could not *keep going* as fast as its petrol rival. But let it not be forgotten that it was a steamer (the Serpollet) that first attained a speed of 75 m.p.h. and that that was in 1902; next year the same car exceeded 90 m.p.h. and in 1906 a Stanley did the mile at a speed of 127 m.p.h. When one of the last and probably the best steam cars to be produced commercially, the American Doble, was in its heyday the story used to be told that it could be put with its bumpers up against a wall with five people in the rear seat and the throttle then opened with the effect of spinning the back wheels until all the rubber was burnt off the tyres. That would be in the late twenties.

With so few modern steam cars to compare or compete with the modern petrol car, comparisons must take us back thirty years and I am not suggesting that a thirty-year-old steamer could compete with all petrol cars of today. The point is that had steamers continued in production they could have been developed and improved just as much as the petrol car has been and given the opportunity I would eagerly back the steamer of 1954 for performance against any petrol car of similar general class—e.g. similar power and price.

If, then, the steamer was so good why did it fall out of production, why have so few of the 125 makes produced in America survived? So far as I can ascertain there is one only. The answer lies partly with the old makers; these were never of the big scale production type and their marketing methods or lack of methods were of the crudest. A sample is to be found in the fact that when a friend of mine was preparing the material for his *Automobiles of the World* at the end of the First World War not one of the steam car makers to whom he wrote for information troubled to answer his letters and so there is no information in this otherwise comprehensive survey about steam cars, of which there were then several in production. When the huge American manufacturing concerns broke into the car market they were naturally enough out for the quickest returns on their cash, and with petrol in apparently unlimited supply at a few cents a gallon who can blame them for taking the line of least resistance?
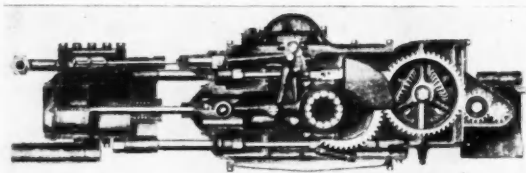

FIG. 5. A section through the Doble engine and rear axle showing how the 4-cylinder power unit drove the differential gear through a spur gear on the engine crankshaft. This coupling of the engine and rear axle was common practice on steam cars.

As for the cars themselves the big troubles with the old steamers were time required to get going from cold and the inability to keep up a head of steam to give cruising speeds as good as those provided by petrol engines. Neither trouble is inherent in the steam engine, the weakness lay at or in the burners that provided the heat under the water-tube boiler. These burners almost invariably used kerosene after being started up on petrol, and they suffered from nearly every trouble that ever beset a picnic vaporising stove, without the advantage of easy access for cleaning or for throwing overboard when the owner became fed-up to desperation. Nevertheless, in the later models signs of real improvement were evident; the burner had a pilot jet that could be left alight all night and the car could then be driven out of its garage in the morning with more certainty and in less time than most petrol cars of the middle twenties could claim. The Doble burner was lit by a sparking plug—no more trouble than switching on the ignition—and it was claimed that the car could be driven out of the garage within 30–45 seconds of switching on. Another claim made for the Doble was that the boiler could maintain a head of 750 lb. per sq. in. so that the car could be driven at 75 m.p.h. indefinitely. But the Doble was a very expensive car—I believe it cost something like £3000, not so much because it was steam but because it was made only in small numbers to special order. There is no reason why a steam car should cost more than a petrol car if made in the same quantities, in fact it might well cost less.

A steam car needs no gear-box, nor indeed any transmission in the ordinary sense and these are costly items in any chassis. In the case of the Delling steamer the three-cylinder engine was mounted vertically behind the boiler under the bonnet and so needed a propeller shaft to the rear axle but, of course, no clutch and no gear-box. In all other recent steam cars the engine and rear axle were a close-coupled unit; usually a single spur pinion on the engine crankshaft engaged with the differential crown wheel, as a matter of convenience rather than of necessity for the gear ratio was usually very nearly 1 to 1 and at 60 m.p.h. the engine speed was little more than 1000 r.p.m. On my present 25 h.p. Jaguar car the engine speed at 60 m.p.h. is 3000 r.p.m., on my Austin A40 it was about 50% more. Think of the difference in wear and tear and remember that the temperature of the steam in the cylinders is between 500° and 750°F as compared with the 4000°F or so of the petrol explosion; also the steam does not explode and *hit* the piston, it expands and pushes it. No wonder steam gives a smoother power impulse even though the engine has no fly-wheel.

If a steam car were designed and produced today, it would almost certainly have a flash boiler, as did the old Serpollet, and it would have a burner with an electrically driven fan, a suitable modification in fact of the oil burners that are now used extensively for boiling water in all sorts of places from central heating systems in private houses to the boilers of the two *Queens*. Such burners were only just being thought of in the days when the steam car disappeared from the market. Another feature—not a novelty—would be a condenser such as enabled the Doble to run for 1500 miles on one filling of water, the condenser

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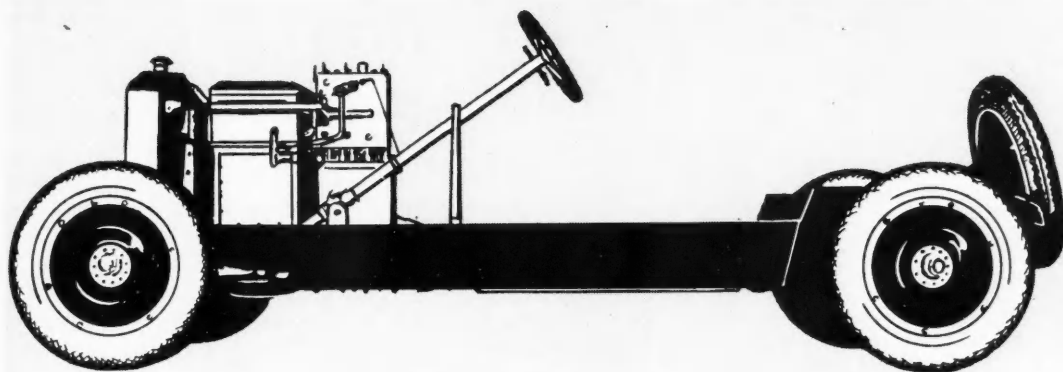steam car
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FIG. 6. The Delling steam car chassis showing the boiler and the 3-cylinder vertical engine mounted under the bonnet, whence power was taken to the rear axle via a conventional propeller shaft.

being of course much the same as an ordinary radiator and occupying the same position. The boiler and burner with the condenser normally occupy the front end of the chassis and also under the bonnet the Doble had an auxiliary plant —a small steam engine—for providing electric services. Steam is taken from the boiler to the engine at the rear of the chassis through a system of piping that gave far less trouble than might be expected, and what petrol engine could be mounted under the rear floor of the car or who would buy such a car if it were? During all the time I used a Stanley I never saw the engine—I wish I could say the same of many petrol engines I have known!

Normally steam-car engines had two double-acting simple cylinders—the steam having done its job in one cylinder was returned to the condenser and thence to the boiler. But the Doble was a compound engine of four cylinders—two pairs each consisting of a high- and low-pressure cylinder the respective bores being $2\frac{5}{8}$ in. and $4\frac{1}{2}$ in. with a stroke of 5 in. There were thus eight power impulses per revolution of the crankshaft as compared with the two of a conventional petrol four-cylinder engine. The smoothness of the steamer is thus explained and so is something else so far not mentioned—its flexibility. Indeed this might well be ranked as a primary asset. In spite of a single gear ratio of 1 to 1 the steam car can be driven at less than normal walking pace quite indefinitely and without any skill or trouble on the part of the driver who can bang open his throttle and throw (literally *throw*) the car forward and his passengers backward and ruin a set of tyres at the same time. Not that he need do so; he can on the contrary increase speed so slowly that only the speedometer and the sound of the wind will indicate that there has been any change at all. And the car will go just as well backwards as it will forwards! The change from ahead to astern is a mere matter of a momentary touch on a pedal.

I said I would try not to let my enthusiasm run away with my judgment and I must show the other side of the picture. I find it difficult if not impossible to conceive a steam car as easy of maintenance as the modern petrol car. When you have a system of some hundreds of feet of steel tubing containing steam at a pressure of between 500 lb. and 800 lb. per sq. in., and water that is never pure, trouble at some time is more than likely. Add to the tubes the check valves and controls, all under this continuous working pressure—well, here you may have the answer to the question: Why has the steam car not survived? But these were the troubles of thirty years ago and none need discourage us today; none is insuperable. Whether the steam car with its comparatively inefficient external combustion engine could ever equal the petrol car in the matter of miles per gallon of fuel is another story but the steamer's paraffin costs only about half as much as petrol so in the matter of finance, which is what matters, the steamer might win after all.

THE INTERNAL COMBUSTION TURBINE

Like the other ideas mentioned, that of the internal combustion turbine is not exactly new but the turbine car certainly is, or would be, unconventional in the sense that none has so far been produced commercially. There is of course no question of the 'workability' of such a car. The question here is whether the advantages are likely to outweigh the disadvantages as compared with the conventional piston engine, in which respect a parallel is suggested with the foregoing remarks about the diesel.

I first heard about the internal combustion turbine during the First World War when a friend told me how he had made one that ran comfortably at 20,000 r.p.m. for an appreciable part of a minute, at the end of which time the turbine blades, made of pen nibs, had disappeared. Like so many other engineering advances in recent times the turbine depends fundamentally on metallurgy, and it is lack of suitable metals that prevented earlier development. Even so the late Lionel Rapson, who tried to revolutionise the tyre world, told me that if he was not ultimately successful with his tyres he had an internal combustion turbine up his sleeve that would revolutionise the car world but it never got any further than this interesting information.

It is hardly necessary to say the internal combustion turbine is now so thoroughly proven by its achievements in

the air that its possible application to road vehicles is inevitable. Credit for the first serious efforts in this direction ought to go to the Rover Company who know at least as much about pioneering in road vehicles as anybody. These efforts received some seal and publicity from the speed achievement of 152 m.p.h. in Belgium nearly two years ago but significantly perhaps there has so far been no serious talk about a turbine car being put on the market for the public, though such a car for a limited market would not be such a very great surprise of this year's Motor Show!

America's first turbine car has now been announced—characteristically, its power is stated to be 370 b.h.p. and its speed 200 m.p.h.!

MORE POWER, LESS WEIGHT

It seems that the once anticipated objection to the turbine, lack of flexibility, has now been largely overcome because it is reported that the Rover turbine car is practically as easy to handle as a piston engine car. Nevertheless when one is told that at 120 m.p.h., which after all is not such a fantastic speed nowadays, the power turbine is turning over at 25,000 r.p.m. it is a bit of a shock when this figure is compared with the 2000 r.p.m. of the old steamer. In the Rover application there are two turbines, one driving a compressor and the other is the power unit generator. When the engine is started the compressor turbine, which incidentally rotates in the opposite direction to the power turbine, is first turned by a conventional starter motor up to about 3000 r.p.m. when it takes over on its own and runs up to its idling speed of 13,000 r.p.m. To take the figures published for the record-breaking car the running speed of the compressor turbine was about 40,000 r.p.m. and of the power turbine, 26,000 r.p.m. to give 230 b.h.p. The total weight of the power unit for this

output of about 200 b.h.p. is some 500 lb. which is little more than half that of the piston-engined power unit of the standard Rover car with a b.h.p. of about 75.

It is too early yet to attempt authoritative opinions on the practicability of the turbine car for ordinary everyday use but the high working temperature inside the power unit and the very high fuel consumption are difficulties that will have to be and doubtless can be overcome. No one doubts that the turbine car will become a practical proposition but estimates as to when are very widely spaced. Personally I shall be surprised if there are many on the roads in less than ten years and it may be worth while bearing in mind that when turbine cars are being developed commercially some bright genius may think of using the steam turbine, which would make a *really* interesting story.

In conclusion may I forestall the criticism that will doubtless occur to some readers that this survey is not exhaustive. Of course it is not; such a thing would fill a good-sized volume. It is not through an oversight that I have omitted to refer to the rotary valve and valveless engines—there was an Itala rotary valve car and a car known as the Valveless, and I have said nothing about the swashplate engine which was certainly an impressive example of ingenuity. Ought I to have included anything about the kinetic energy fly-wheel unit used on the Swiss so-called gyro-bus? The fly-wheel is speeded up by an electric drive at each of two terminal points about a dozen miles apart and it runs backwards and forwards the journey each way taking about half an hour. The same idea is applied to delivery trucks in factories and places where there might be serious fire risk as in oil refineries and the like. Understandably this might be a practical power unit but it obviously has very definite limitations which must be the excuse for not giving it fuller treatment here.

PROGRESS OF SCIENCE—*continued from p. 145*

analogue of carbon tetrachloride. This is prepared by treating sand with chlorine gas at a high temperature (1000°C). Silicon tetrachloride is a liquid, which boils at 57·6°C. Organosilicon compounds—i.e. compounds containing both carbon and silicon—can be derived from silicon tetrachloride via the famous Grignard reaction. These compounds can also be synthesised by another method—the olefine-addition method, which depends on the preparation of silico-chloroform ($HSiCl_3$), which is then heated with an unsaturated organic compound: this method proceeds according to the following equation:

$$RCH = CH_2 + HSiCl_3 \rightarrow RCH_2 - CH_2 - SiCl_3$$
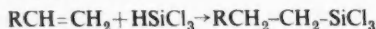
A third method of synthesis involves the use of sodium metal (or potassium or lithium) in place of the

magnesium upon which the Grignard reaction mentioned above depends.

The scientific and technical details of silicone preparation are well described in McGregor's book, to which we would refer any reader who wants more information. Scientifically these silicone compounds are interesting, and in view of the fact that it is theoretically possible to replace any carbon atom by a silicon atom in most organic compounds the range of organosilicon compounds which will eventually be synthesised is likely to be very large. The silicones that are already on the market are coming into everyday use to an ever-increasing extent. Silicone polishes are already obtainable in Britain, and in the months to come it will be interesting to watch for other silicone preparations to become available in the shops.

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A FIRST
TRACER MINERAL

ASHLEY G. LOWNDES
Sc.D., F.R.I.C., F.G.S.

(Right) FIG. 1. *A section of Wolf Rock phonolite. Magnification ×20. Two crystals of nosean are labelled N; and two sanidine crystals, S. The ground mass is composed of small crystals of sanidine, nosean and aegerine; nepheline is also present but can only be identified by a microchemical test (from "British Petrography" by J. J. Harris Teall).*

Tracer elements or tracer isotopes have been used in biology for a good many years, but the use of a tracer mineral in oceanography is, I believe, quite new although it would appear that nature has provided an ideal one on the coast of the British Isles.

In spite of the enormous amount of work which has been done and is being done, comparatively little is known about the direction of the deep-water or bottom drift of water around the British Isles, and it is just possible that a good deal of information may be obtainable by the method to be described.

Eight miles south of Land's End stands an isolated rock, The Wolf Rock with its famous lighthouse, and this rock consists of a special type of igneous rock known as a *phonolite*. Phonolites are very rare rocks in the British Isles, though they are fairly common on the Continent, but fortunately they are found many miles from the sea and well away from the coastal waters of the British Isles. In fact nothing like the Wolf Rock occurs elsewhere on the whole of the coast of the British Isles. The Wolf phonolite was described thoroughly by J. J. Harris Teall in 1888 (*British Petrography*, Dulau & Co., London) so there is no need to go into details here, beyond saying that it contains a somewhat obscure mineral called *nosean* as well as a quite common mineral called *sanidine* (which is a felspar). Now nosean by itself would be quite useless as a tracer mineral for it is a somewhat soluble sodium aluminium silicate coupled with sodium sulphate; thus the nosean by itself would readily disintegrate and disappear were it not for the fact that it occurs in two forms.

In the case of the Wolf Rock phonolite we are dealing with what is called a porphyritic rock. This simply means that the parent molten rock, or magma, cooled *in two stages*.* In the first stage it cooled very slowly and under great pressure, very often with the production of large crystals. Then for some reason a change took place, and the rest of the magma cooled more quickly and probably under lower pressure. The general effect is that you find

crystals of the same mineral perhaps in two forms; there are the large crystals (phenocrysts) or the small crystals which make up the ground mass. In the Wolf Rock we are indeed fortunate, for the nosean occurs as fairly large phenocrysts (which would, however, soon degenerate when they come in contact with the sea-water) and also as minute crystals which are enclosed in the sanidine. Now sanidine is a clear, colourless and transparent mineral which is as insoluble in sea-water as almost anything can be, and hence these inclusions of nosean are hermetically sealed off from contact with the sea-water. Thus as the Wolf Rock gradually disintegrates the flakes of sanidine are carried farther and farther away in the direction of the deep or bottom drift and deposited there.

Clearly then, if during the course of dredging you come across the nosean embedded in the sanidine, you know it can only have come from one place—the Wolf Rock.

When the method was first propounded it received very scanty support. It was thought that it would be like hunting for a needle in a very large haystack, but really this is not so. The sand surrounding the coast of the British Isles consists very largely of rounded or subangular grains of quartz, and a certain amount of felspar, plus other minerals which are often highly coloured, but fortunately nearly all these other minerals have a density which is higher than that of the phonolite and its constituent minerals. The density of the phonolite is 2·54, while that of quartz is nearly 2·8, and the density of almost all the other common minerals is still higher. The technique then of separating out the sanidine with its inclusions is quite simple.

You first clean your sand with dilute acid to get rid of the mud and shell and then dry it, and you then place a fairly large part of your sample in a solution which has a

* It must be remembered, however, that the consolidation of these magmas is at present a much-disputed point. The view expressed here is that of the older petrologists such as J. J. H. Teall and Alfred Harker. However, whatever the theory, the fact remains that both the sanidine and the nosean do occur in the two crystal forms described.
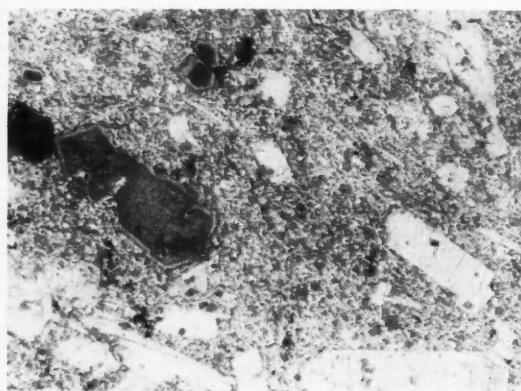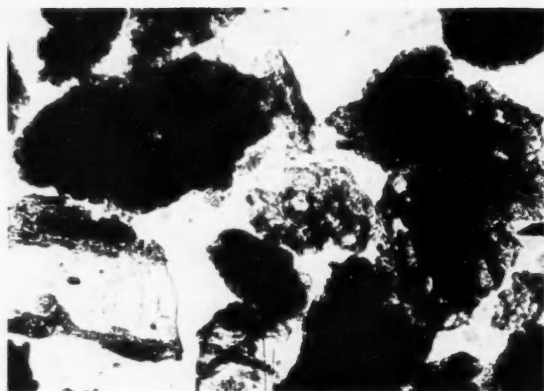
FIG. 2 (*left*). Nosean grains from the Wolf Rock. FIG. 3 (*right*). Photomicrograph of Wolf Rock phonolite showing large crystals of nosean and sanidine; compare with Fig. 1.

density of 2·6. The quartz and other minerals sink while the sanidine and nosean floats. It is then readily skimmed off and examined under the mineralogical microscope. Here again luck is very much on our side. Transparent and colourless minerals are largely identified by their *refractive index*, which can be determined with comparative ease by the petrologist or the mineralogist using the proper microscope. In fact this recognition of a difference of refractive index constitutes one of the chief tools in the identification of colourless minerals under the microscope. Now most rock-sections or sand grains are permanently mounted in Canada balsam. The refractive index of the Canada balsam is very close to 1·538 while that of sanidine is about 1·52. Few minerals have a refractive index as low as this, and hence sanidine mounted in Canada balsam can hardly be mistaken for anything else. Nosean has a refractive index which is still lower. Hence under the microscope one steps, so to speak, from Canada balsam down to sanidine and then again down to the nosean. This test of the mineralogist is a very reliable one, and one which is easily applied; furthermore, it has the almost superlative value that it can be applied to the most minute flakes of these two associated minerals.

One big difficulty arose over the dredging, for it meant the use of a long-distance trawler. The Wolf Rock is practically a hundred miles from Plymouth, and although the Marine Biological Association possesses two ocean-going trawlers these are generally engaged on routine work, and of course it is only possible to approach the Wolf Rock and do the necessary dredging in fine weather.

The difficulty was, however, overcome through the keenness and generosity of Major H. W. Hall, who owns a very fine motor launch, *Manihine*, which he readily put at my disposal, and he and I together with the crew to whom I am also indebted, were able to make the voyage on July 22. The weather was very favourable and everything went well. We collected eight samples. Four inner ones from one mile north of the Wolf and one from one mile

east, etc. Then we made four outer dredgings but this time they were five miles from the Wolf.

I thought that the working through the samples would be a long and tedious task, in spite of the simplicity of the method, but again fortune favoured us. It was suggested that I might be able to locate the nosean half a mile away from the Wolf, if we were ever able to dredge from there, but beyond that it was thought to be highly improbable.

I tackled the samples quite at random, and by that I mean I first examined a sample without first looking up its location, and found that I could pick out, not minute flakes, but small pebbles of phonolite nearly a third of an inch across, and on looking up the reference for the location I found they had been dredged from a spot five miles east of the Wolf.

The samples were too irregular, or meagre in some cases, to justify any real conclusion at present, but obviously if small pebbles can be carried in the one direction five miles from the Wolf, minute flakes should be carried probably a hundred times as far.

In the Wolf Rock there seems to be therefore an almost ideal tracer mineral for investigating deep-water or bottom drift.

It is just possible that there may be other exposures of phonolite not yet located but it seems hardly likely. If there are, then the search for phonolite should locate them. Any information of that kind would always be useful, but a pretty thorough investigation of the boulders found on the floor of the British Isles has been going on for some time and no phonolite has been recorded yet.

Much work has been done on the investigation of sediments around the coast of the British Isles but these have been concerned with off-shore deposits. Here we are concerned with drift in the opposite direction.

I feel that a great deal more might be done with this question of mineral association as shown by the investigation of mineral grains. It is a weapon or tool which might be used more frequently with advantage.

ROBERT JAMESON AND
THE ROYAL SCOTTISH MUSEUM

V. A. EYLES
B.Sc., F.R.S.E., F.G.S.

This year's centenary of the Royal Scottish Museum in Edinburgh provides a singularly appropriate occasion for an appreciation of one of Edinburgh's more famous citizens, Professor Robert Jameson, who died in Edinburgh on April 19, 1854. Not only was Jameson Regius Professor of Natural History in Edinburgh University for fifty years, but it was to him more than any other single individual that Edinburgh owes the establishment of its National Museum in Chambers Street. The immediate forerunner of the present museum was a University or College Museum. It was through Jameson's enthusiastic labours over many years that the College Museum attained such size and status that the State became interested in taking it over and making it a National Museum for Scotland.

EARLY YEARS OF THE EDINBURGH MUSEUM

The roots of the present museum extend far back, into the latter years of the 17th century, since when there has always been a collection of natural history specimens of sorts housed in the buildings of the University, or the 'Town's College' as it was for long known.

It may be well to diverge here for a moment to explain the relationship between the civic authorities and the University, since this has a definite bearing on the origin of the present museum.

Originally, unlike the older Scottish universities, which were founded by Papal Bull in the 15th century, the University of Edinburgh was constituted, in 1583, as the 'Town's College', under powers given by a Royal Charter. This change in procedure resulted from the abolition of the jurisdiction of the Papacy in Scotland by Act of Parliament in 1560. Its consequence was that, for very many years, the College was subjected to a considerable measure of control by its patrons, the civic authorities. This becomes apparent when one traces the events leading to the establishment of the present museum, and some account of the early history of the University Museum is therefore of interest.

The first attempts to get together a collection of natural history specimens in Scotland were made by two friends, both distinguished physicians, Sir Andrew Balfour and Sir Robert Sibbald. To the joint efforts of these two Scotsmen their country also owes the foundation of both the Royal College of Physicians and the Royal Botanic Garden in Edinburgh.

Balfour's wealth, coupled with the fact that he travelled widely, gave him exceptional opportunities for making such a collection. His activities paralleled those of Sir Hans Sloane, whose museum, some sixty years later, formed the nucleus of the British Museum collections in London. Balfour spent fifteen years on the Continent, studying medicine and acting as tutor to a young nobleman, the Earl of Rochester, and he is said to have returned "loaded, as it were, with the spoils of foreign nations". His collections included an extensive library of works on medicine and natural history, as well as a large collection of fossils, plants and animals. After his death in 1694, the private museum which he had assembled over forty years was deposited in the Town's College.

Meantime, Sir Robert Sibbald had also spent some years in gathering together a collection, in his case specially with a view to illustrating the natural history of his native country. Sibbald published in 1684 a work entitled *Scotia Illustrata sive Prodromus Historiae Naturalis*, in which he figured Scottish birds, fishes, plants and fossils. This was the first systematic work of its kind, as far as Scotland was concerned. In 1697 he presented his collections to the College, and published an account of them bearing the title *Auctarium Balfouriani e musaeo Sibbaldiano* (Additions to the Balfour collection from the Sibbald Museum).

The Town Council's interest in the museum was recorded at a very early date, in the form of an Act of Council respecting General Directions as to Library and Museum, dated June 29, 1698; there was another Act, dated May 19, 1703, "anent Rarities for the College Museum".

Soon after, in 1705 to be precise, the Royal College of Surgeons in Edinburgh appointed one Robert Elliott to take sole charge of the teaching of anatomy, and he petitioned the Town Council for some pecuniary reward for undertaking this task. They granted him £15 a year as an encouragement in his profession, but with the express provision "that the petitioner take exact notice and inspection of the order and condition of the rarities of the College; and that an exact inventory be made of the same and given to the Council". How much interest Elliott and his successors took in the museum is obscure, but it was probably very little. However, Defoe, in the third volume of his *Tour thro' the whole Island of Great Britain* (1727), calls it a "curious and noble museum", containing "a vast treasure house of curiosities of art and nature . . . greatly valued by the virtuosos".

In 1764 the Incorporation of Surgeons in Edinburgh proposed the transfer of their collection of natural curiosities to the College Museum. Possibly arising out of this offer, which was accepted, Principal Robertson petitioned the Town Council in 1765 to fit up a room as a museum, and £150 was granted for this purpose, so

FIG. 1. The College Museum, Edinburgh. (*From The Edinburgh New Philosophical Journal, 1854.*)

evidently the Council retained an active interest in its museum.

There followed, shortly afterwards, an event that was ultimately to prove of great importance in the affairs of the museum. A Chair of Natural History was established in the University, for the first time, by Commission from George III in 1767. A Dr. Robert Ramsay was appointed by the Crown to fill the Chair, but even so, it was necessary for him to petition the Town Council before he could be admitted as Professor. In granting his application the Council also appointed him Keeper of the Museum, on conditions that included the delivery to the Clerk of an inventory of the curiosities belonging to the University. As far as lecturing was concerned, Ramsay seems to have regarded his post as a sinecure, but he may have put some work into the museum. One finds conflicting reports by the naturalist Thomas Pennant, who visited Edinburgh in 1769 and 1772, concerning its condition.

Ramsay only held his appointment for a short period, and after his death in 1779 a man of very different calibre succeeded him. This was Dr. John Walker, a Scottish clergyman of great ability and already a naturalist of repute. Walker records that Balfour's Museum had remained for many years useless, neglected and decaying, but that even after 1750 it was still a considerable collection. He states that he had good reason to remember it, because it was this collection that inspired his attachment to natural history. He goes on to say that soon afterwards it was removed from the hall in which it was kept, and thrown aside as lumber; but that in 1782, soon after his appointment, he rescued many still valuable and useful pieces from the 'ruins and rubbish', and put them in the best order he could. Here it is of interest to quote the remarks of a distinguished French geologist, Faujas de St. Fond, who passed through Edinburgh shortly afterwards, in 1784. He records that:

"the cabinet of Natural History in the University, is under the direction of Dr. Howard.* This collection gave me

more pleasure, and interested me more than that of the British Museum in London, though it is far less considerable; but, the objects which compose it, are in a more methodical order, particularly the stones and minerals. They have here had the good sense to collect all the productions of Scotland which they have been able to procure".

It is interesting to note the improvement in the museum that had taken place since Walker became Professor, especially in the geological and mineralogical collection. Walker had travelled widely in Scotland and England, and wherever he went he took the opportunities offered to collect minerals. While he evidently had a special leaning towards minerals, he was also a competent botanist. His lecture course was comprehensive, including Zoology, Botany, Hydrography and Meteorology, as well as Geology and Mineralogy, and doubtless he built up a collection adequate to illustrate his lectures.

About this time some acquisitions to the University Museum were obtained from another source. In the first charter of the Royal Society of Edinburgh (which was founded in 1783), it was laid down that the specimens of natural history belonging to the society should be placed in the custody of the University. Under this rule one collection of great historic interest passed to the University. This was the collection of James Hutton, whose classic *Theory of the Earth* was first announced in Edinburgh, at a meeting of the Royal Society, in 1785. After Hutton's death in 1797, his sisters presented his collection of stones and fossils to his great friend Joseph Black, the chemist. Black expressed a wish to present them to the Royal Society on certain conditions. One of these was that the specimens should not be dispersed, but preserved as a collection, and committed to the custody of four trustees, one of whom was to be the Professor of Natural History in the University, "with liberty to lay them open occasionally to the inspection of intelligent persons". Later on the Royal Society changed their mind about handing over specimens to the University Museum.

When Walker died, in 1803, the Town's College Museum still survived, after a somewhat chequered existence that had lasted more than a hundred years. The creation of a Chair in Natural History whose occupant was *ex-officio* Keeper of the Museum had already led to improvements, and it held out the promise that still more flourishing days lay ahead for the museum. When, in 1804, Walker was succeeded by his former pupil and assistant, Robert Jameson, this promise was fulfilled. Jameson, quite apart from his long connexion with the museum, had a long and distinguished career as a naturalist, which it is convenient to describe now.

ROBERT JAMESON (1774–1854)

Robert Jameson was born in Leith on July 11, 1774. It is recorded that his early reading included Defoe's *Robinson Crusoe* and the accounts of Cook's voyages to the Pacific. Whilst still at school, he also displayed a

* Who Dr. Howard was does not appear, but it may be presumed he was an assistant to Dr. Walker.

great interest in natural history, and frequently played truant to collect specimens on the shores of the Firth of Forth. Stimulated by his natural inclinations and his reading, he expressed a desire to make the sea his profession, so that he could gain opportunities to study nature in other countries. To this his father objected, and friends suggested he might acquire more insight into natural history by taking up the study of medicine. Accordingly, he was apprenticed to a Leith surgeon, John Cheyne. In 1792, at the age of eighteen, he commenced to study at the University and of course attended the lectures of Professor John Walker. He became a favourite pupil of Dr. Walker, and not long afterwards he was given charge of the museum. He also added botany to his interests at this time. In the following year he spent some months in London, where he made the acquaintance of Sir Joseph Banks and other members of the Linnean Society, and also studied the various natural history collections in the metropolis. On his return he gave up his post as assistant to Mr. Cheyne in Leith but continued to pursue his medical studies in the University, attending classes in anatomy and chemistry. Joseph Black was at that time Professor of Chemistry. Black's successor was T. C. Hope, and a friendship sprang up between him and Jameson. Both men were interested in geology, but in this sphere they were destined to join opposing camps.

It is apparent that Jameson's interest in geology arose when he was quite young, which is not surprising, because at that time Edinburgh was a centre of geological thought. James Hutton himself was resident in the city until his death in 1797, and other notable geologists, followers of his, survived him. The teachings of the great German geologist, Abraham Gottlob Werner had also reached Scotland, and he too had his supporters in Edinburgh. This was a period when the city was a veritable hive of intellectual activity, and students from all over Britain, the Continent and America were attracted to it. Jameson could not have been born at a more favourable time or place in which to develop his natural inclinations. Geology, as we shall see, was to become his favourite study.

Jameson took advantage of the fact that his father was willing to provide the means for travel, and between 1794 and 1800 he journeyed extensively in Western Scotland and the Western Islands, and he also visited the Orkneys and Shetland. As a result of these excursions he published in 1798 a *Mineralogy of Arran and the Shetland Isles*, and followed this up in 1800 with the *Mineralogy of the Scottish Isles: with Mineralogical Observations made in a Tour through different parts of the Mainland of Scotland*. These works are geological classics, being the first systematic accounts of the geology of considerable parts of Scotland. Incidentally, their contents indicate that already Jameson had acquainted himself with the teachings of both Hutton and Werner.

In 1800 Jameson travelled to Germany to study under Werner in the mining town of Freiberg, in Saxony. Here he remained for nearly two years, only returning because of his father's illness. This visit was a turning-
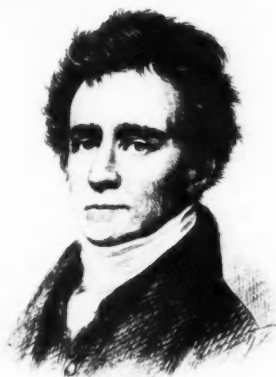
FIG. 2. Robert Jameson, Regius Professor of Natural History in the University of Edinburgh, 1804–54.

point in his career, so far as his reputation as a geologist was concerned. The School of Mines at Freiberg was then famous throughout Europe. It had gained its reputation through the outstanding personality of Werner, who lectured there on geology as well as mining, and attracted students, and indeed older men already well versed in geology, from all over Europe. Here Jameson undoubtedly fell under the spell of the master, and absorbed, uncritically, all that he had to say.

Little more than a year after his return Dr. Walker died and, in 1804, Jameson succeeded him in the Chair of Natural History. Thus, at the early age of thirty, his life's work began. This, as we shall see, was to be the foundation of a school of Natural History whose fame was to extend far beyond the confines of Scotland, and at the same time to build up a Natural History Museum of such size and interest that it was taken over by the State as the nucleus of the Natural History collection of the present museum.

Meantime, however, his new post at once put him in a position to expound his views on geology, and he became the greatest protagonist of the Wernerian doctrines in Scotland, and indeed, in Britain. From now on he taught what he called *geognosy*, to distinguish it from geology, which, according to Werner, was a term only to be applied to idle and imaginary speculations respecting the formation of the earth. A discussion of the relative merits and defects of the Wernerian and Huttonian schools of thought, which are now only of historic interest, would be out of place here. One fundamental difference between them needs to be mentioned, however. The Wernerians believed that practically all rocks, including crystalline silicate rocks such as granite and basalt, had been deposited from water as sediments; on the other hand, the Huttonians maintained that the latter rocks were formed by the consolidation of molten matter that had risen from the earth's hot interior and solidified in or on the cool outer layers of the earth's
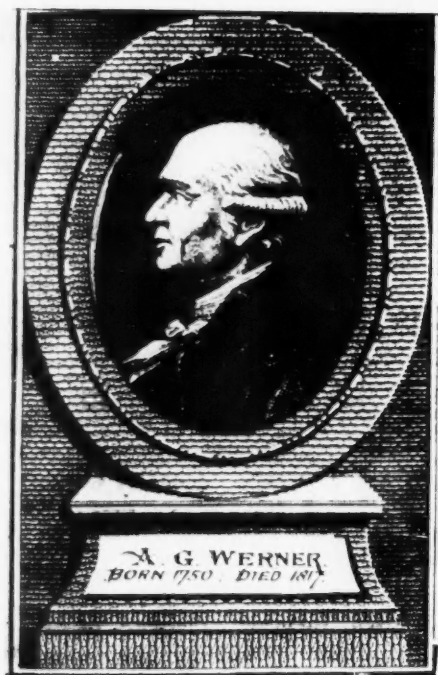
FIG. 3. Abraham Gottlob Werner, appointed Inspector of Collections and Teacher in the School of Mines, Freiberg, in 1775, a post he held until his death in 1817.

crust; that is to say, they were *igneous* rocks. Hence the Wernerians came to be known as *Neptunists* and the Huttonians were termed *Plutonists*. For a number of years, particularly in Edinburgh, a bitter controversy was waged between the two schools of thought, with the Huttonians eventually emerging as victors. A distinguished American, Benjamin Silliman, founder of the *American Journal of Science*,* who visited Edinburgh in 1805, recorded that "the followers of Hutton are now organized into a geological phalanx, and my residence occurred at the fortunate crisis, when the combatants on both sides were in the field; and I, although a non-combatant, was within the wind of battle, and prepared, like victory, to join the stronger side".

Sir Henry Holland, a physician who was in Edinburgh in 1806, gives another account of the dispute. He wrote that "A minor and more whimsical cause of disruption in the Edinburgh society was the controversy going on between the Huttonians and the Wernerians, as they were then called . . . which grew angry enough to show itself within the walls of a theatre . . . A play written by an ardent Huttonian, though graced with a prologue

* This was started as *The American Journal of Science and Arts* at New Haven in 1818; it was so much the creation of its editor that it soon became known as 'Silliman's Journal'. After 1880 its title was changed to the *American Journal of Science*.

by Walter Scott and an epilogue by Mackenzie (the author of the 'Man of Feeling') was condemned the first night—as many persons alleged, by a *packed house* of the Neptunian school. It may be that the play itself was more concerned in the fate that befell it".

There can be very little doubt that after his return to Edinburgh Jameson adopted an attitude of extreme dogmatism in geological matters, which was quite contrary to the true spirit of scientific inquiry. He allowed his enthusiasm for the teaching he had absorbed at Freiberg to outrun his judgment, though it should be noted that he had exhibited leanings towards the Wernerian views even before he visited Germany. In 1796 he read an address entitled "Is the Huttonian Theory of the Earth Consistent with Fact?" to the Royal Medical Society in Edinburgh, and in this he criticised Hutton.

On his return from Germany Jameson hastened to expound his views in print in a three-volume *System of Mineralogy*. The first volume, which appeared in 1804, received a scathing notice in the *Edinburgh Review*. "No devotee," wrote the reviewer, "ever more zealously maintained the infallibility of the Pope, than Mr. Jameson has done that of his master"; and added "It might possibly escape the author's modesty, indeed, that his work was likely to become obsolete before he rendered it comprehensible; but to the malicious perspicacity of a Reviewer, such a possibility occurred with instinctive readiness".

Jameson had been elected a member of the Royal Society of Edinburgh in 1799, and an honorary member of the newly formed Geological Society of London in 1807, but he never contributed to the publications of these societies. In fact, he founded a new society in 1808, the Wernerian Natural History Society, whose Memoirs were to become a platform for expressing the views of the Neptunians. Jameson was the president as long as it existed. This society continued to publish until 1839, but after 1820 or thereabouts, contributions from geologists who were not strict Wernerians began to find a place in its pages. It was not, however, an exclusively geological publication, and included many papers on other branches of natural history.

Although Jameson adhered to Wernerian views for many years, it is pleasant to be able to record that ultimately he accepted those teachings of the Huttonians that had stood the test of time. An anonymous biographer relates that he made known his change of opinion "particularly in different meetings of the Royal Society [of Edinburgh] with perfect candour and love of truth". The same writer also tells us that "in the class room, minerals were thought by many to occupy an undue share of the course"; but he also places to the credit side of Jameson's teaching the statement that his field excursions "did more towards the making of geologists than any instructions that had been given within the century".

It must not be thought that Jameson's enthusiasm for geology implied any neglect of the other branches of natural history. The field covered by his university

lectures was wide, including Meteorology, Hydrology, Mineralogy, Geology, Botany and Zoology; and of course, he spent much time in curating and enlarging the University Museum. Throughout his life, too, his literary output was very large. He completed his *System of Mineralogy*, totalling more than 1500 pages, between 1804 and 1808. The last volume, entitled *Elements of Geognosy*, was intended as a class textbook. In 1805 he produced his *Mineralogical Description of the County of Dumfries*, and also a *Treatise on the External Characters of Minerals*. In 1821 he published a *Manual of Mineralogy*. Some of his textbooks appeared in several editions. He also contributed upwards of fifty papers to the Memoirs of the Wernerian Society and other scientific periodicals; nor was his output confined to geological subjects, for it included papers on other branches of natural history. He also wrote articles for several important encyclopaedias. In 1819, he undertook still another task; in association with David Brewster he became joint editor of a new publication, the *Edinburgh Philosophical Journal*. After 1824 the association broke up and Jameson continued as sole editor until his death. Evidently he was very much occupied with literary matters all through his long life.

Here we may pause to inquire what manner of man he was personally, and how his lectures were received. First it may be of interest to quote the opinions of some of the many distinguished men of science who attended them at one time or another.

Sir Robert Christison, who later occupied successively the Chairs of Forensic Medicine and Materia Medica in Edinburgh University, tells us that in 1816 the "lectures were numerously attended in spite of a dry manner, and although attendance on Natural History was not enforced for any University honour or for any profession, the popularity of his subject, his earnestness as a lecturer, his enthusiasm as an investigator, and the great museum he had collected for illustrating his teaching, were together the causes of his success".

A still more famous student, Charles Darwin, went to Edinburgh to study medicine at the age of sixteen years and eight months, and attended Jameson's lectures in his second year, 1826–7. He records that "they were incredibly dull. The sole effect they produced on me was the determination never as long as I lived to read a book on Geology, or in any way to study the science . . ." It seems that even then Jameson was still upholding Wernerian views which Darwin could not swallow. (Fortunately for posterity Darwin changed his mind about geology, and read the first volume of Lyell's classic *Principles of Geology* during the voyage of the *Beagle*.)

Darwin attended meetings of the Wernerian Society in Edinburgh and there he heard, among others, the American ornithologist Audubon, who spoke at meetings in 1826 and 1827. Audubon had letters of introduction to Jameson, and he relates that he was received "with great coldness". A little later the ice seems to have thawed, and he breakfasted with the professor in his "splendid house". Audubon noted "The professor's

appearance is remarkable and the oddities of his hair are worthy of notice. It seems to stand up all over his head and points in various directions, so that it looks strange and uncouth. Around a rough exterior he owns a generous heart, but which is not at first discernible". Audubon's comment on Jameson's coiffure is somewhat surprising, for he himself had astonished Edinburgh society by his hair style. (Audubon's hair hung down in ringlets to his shoulders.)

In the years 1827–8 a distinguished Scotsman, James D. Forbes, who soon afterwards became Professor of Natural Philosophy in Edinburgh, attended some of Jameson's lectures. He describes him as "plain, practical, not to say prosaic, but accurate, painstaking, and diligent as an observer", and adds that he "so rarely ventures on figures of speech that the one or two metaphors in which during the whole session he indulged were well known, and waited for, and when produced were welcomed with annual rounds of applause".

The American botanist, Asa Gray, who visited Edinburgh in 1839, also recorded his opinion of Jameson and his lectures. He speaks of Jameson, who was then about sixty-five years old, as "a stiff, ungainly, forbidding-looking man, who gave us the most desperately dull, doleful lecture I ever heard. It was just like a copious table of contents to a book—just about as interesting as reading a table of contents for an hour would be; I may add just as instructive".

These reminiscences tell us that at any rate Jameson was not an inspiring lecturer, but a more appreciative picture of the man is that given by another student, George Wilson, later Professor of Technology in the University of Edinburgh. He states, writing shortly after Jameson's death, that:

"Natural History . . . was represented in the University of Edinburgh by Professor Jameson, who had won for himself a European reputation as a naturalist, and was surrounded, when Edward Forbes first made his acquaintance,[*] . . . by a band of eager students of Natural History, some his peers, others his pupils. Jameson was a remarkable man. Grave, taciturn, and reserved in manner, devoted especially to mineralogy, the narrowest in some respects of all the departments of the science he professed, he seemed much better fitted for the secluded life of a student, than for the duties of a University Chair. Nevertheless, there was in him a deep, quiet enthusiasm for his favourite science, which his ungeniality of nature could not prevent being contagious, and he became, what many of his brilliant colleagues failed to become, the founder of a School. The spectacle of his perseverance, earnestness, and life-long devotion to his work, overcame the effect of his taciturnity and reserve. These were incurable peculiarities, which probably he would have been as well pleased as others to exchange for their opposites. After all, however, they formed only a tough rind to the man, like that of a pomegranate, which when pierced yields a pleasant juice, fragrant and sweet, though not without acidulous sharpness. Intercourse with him, accordingly, soon dispelled the notion that he was a man wrapped up in himself, happy only when fingering minerals. Side by side with some of the narrowest opinions, which he held and defended most obstinately, was a wide and intelligent sympathy with the progress of every department of physical science."

[*] In 1831. The quotation is from G. Wilson and A. Geikie's *Memoir of Edward Forbes*, 1861.

To supplement the above account, it is worth adding a quotation from the eulogy pronounced by one of Jameson's most distinguished pupils, Edward Forbes, in his Inaugural Address on succeeding Jameson in the Chair of Natural History:

"Who that in time past was his pupil and found pleasure in the study of any department of Natural History, can ever forget his enthusiastic zeal, his affection for all among his friends and pupils who manifested sincere interest in his favourite studies? When, in after life, their fates scattered them far and wide over the world, . . . none who remained constant to the beautiful studies of his pupilhood was ever forgotten by the kind and wise philosopher, whose quick and cheering perception of early merit had perpetuated tastes that might have speedily perished if unobserved and unencouraged. The value of professorial worth should chiefly be estimated by the number and excellence of disciples. A large share of the best naturalists of the day received their first instruction . . . from Professor Jameson. Not even his own famous master, the eloquent and illustrious Werner, could equal him in this genesis of investigators. Valuable as were his writings—each when estimated with regard to the position of science at the time of its issue—his pupils were even more valuable. The greatest praise of a great Professor is that which proclaims he has founded a school. And where else in the British Empire, except here, has there been for the last half century a school of Natural History?"

But the unrepentant Darwin, writing to J. D. Hooker about Forbes' Address, said "I wish, however, he would not praise so much that old brown dry stick Jameson"!

A testimony to the respect in which Jameson was held in Edinburgh is afforded by the fact that, on his death, he was accorded a public funeral, attended by the Senatus Academicus and the Magistrates.

Thus passed a man who, whatever his failings, earned the high respect, not only of the scientific world, throughout Europe and America, but also of his fellow citizens in Edinburgh. Though he made no outstanding original contributions to science himself, through his labours others were inspired to do so. We must now pass on to describe the establishment of his most lasting memorial, the Natural History Museum, to which he devoted so much of his time and energy for fifty years.

JAMESON'S MUSEUM

When Jameson took up his new appointment, in 1804, the university buildings were in a deplorable condition. The foundation stone of a New College (today this is called the 'Old College') had been laid in 1789, but the work of building proceeded slowly, and it was not until 1820 that adequate accommodation became available for the museum, though when it did materialise it was on a generous scale. The museum, too, had been sadly depleted. Undaunted, Jameson at once commenced the task of building up a new collection, and this remained one of his main interests throughout his long tenure of the Chair of Natural History. During these years he encountered all the usual troubles to which present-day curators are liable, lack of accommodation, lack of funds, and interference from well-meaning but perhaps ill-informed bodies with a claim to some say in the museum's affairs. During the fifty years he held the

position of Keeper, the Town Council maintained its interest in the museum, and intervened in its affairs from time to time. One author states they were animated by a restless spirit of interference, but they certainly helped financially on occasions.

One of Jameson's first difficulties was that on Dr. Walker's death his collections were claimed by his trustees, for the benefit of his estate. They included a valuable collection of minerals, and probably an important collection of botanical specimens. What precisely happened to the Walker collections is not known, but in 1821 the Rev. John Fleming (later Professor of Natural Science in the New Free Church College, Edinburgh) wrote that not long before that date whatever remained of Walker's material in the University was still lying in a damp room, the minerals "covered with dirt and grease" and the zoological collections "annihilated . . . by mites and moths". So it appears that Jameson had not been able to make use of them.

Then there were the accessions of specimens from the Royal Society of Edinburgh, which had come to the museum under the terms of the Society's original Charter. The Hutton collection (of which Jameson was *ex officio* a trustee), had already been handed over, and this particular acquisition for some years formed a bone of contention between Jameson and the Society. Some unpublished papers of Jameson* indicate that in 1804, the collection had not been catalogued, and that in spite of the fact that Jameson was a trustee, the Royal Society had put difficulties in the way of his obtaining access to it, one of the grounds on which the Society justified its action being that he was 'disputacious'. One is tempted to suspect that the Society may not have been anxious to hand over the collection of one of its most distinguished members to a young, and, perhaps at that time, rather arrogant young professor who was an opponent of Hutton's views. There were, however, other reasons put forward and the matter went so far that the Society took legal action to alter its Charter. The new charter, dated 1811, enacted that in future the Society's collections were to be retained and placed in charge of its own Librarian. This new law was not made retrospective, and so the Hutton collection remained in the museum. When we next hear of it, the position had been reversed, and it was now Jameson who was preventing Fellows of the Royal Society from obtaining ready access to it. For a time, apparently, there had been no trouble, but when the public was admitted to the museum for the first time—at a charge of half a crown—Jameson tried to impose this charge on Fellows of the Society wishing to inspect their own collections! This was a domestic dispute, but one thing seems certain, that up till 1827 at least, the Hutton collection was never exhibited in the main museum rooms, but was stored in some small annexe. Jameson, while prepared to admit its historic interest, attached no value to it for teaching purposes. (What is still more regrettable is that, today, all trace of the collection has been lost.)

* Consulted by kind permission of Dr. L. W. Sharp, Principal Librarian of Edinburgh University.

However, in spite of these distractions, Jameson rapidly accumulated fresh material for the museum, first of all from his private collections. But these were not enough, and in 1807 he obtained Treasury permission to circulate to Crown officers in all foreign dependencies of the Empire printed instructions for collecting natural history specimens. The museum benefited considerably from this action, but in addition Jameson always asked his own students to add to the collections after they left Edinburgh, and it is a tribute to Jameson that these requests also were acted upon with considerable advantage to the museum.

Between 1804 and 1812 the cost of curating the museum was paid partly by the Town Council and partly by Jameson himself. In the latter year Jameson appealed to the Honourable the Barons of His Majesty's Exchequer in Scotland for financial aid, and they agreed that £100 per annum should be paid to the Professor of Natural History in the University for the use of the museum.

Sometime before 1819 a further important concession was obtained from the Treasury. They sanctioned the importation of specimens for the museum duty-free, a privilege that was frequently used.

In 1819 a very large collection in Paris, the property of the French naturalist M. Dufresne, was purchased for £3000. It contained upwards of 20,000 specimens, mainly of zoological interest. Such great importance was attached to this acquisition, that the University authorities persuaded the Admiralty to send a cutter to Le Havre to collect it and deliver it at Leith.

Meantime, in 1816, work on the new University buildings had been resumed, after a stoppage due to lack of funds, and in 1820 the new Regius Museum was opened, the interior having been fitted out under Jameson's supervision. It occupied the whole of the west side of the quadrangle in what are now known as the Old University buildings. These rooms give an indication of the size of the collections at that time, and of the importance attached to them by the University authorities.

In December of that year arrangements were made to admit the public to the museum on certain days. An admission fee of half a crown was fixed. This was partly to provide a fund for the upkeep of the collections, and partly to meet the interest on a debt incurred by the purchase of the Dufresne collection. Two shillings and sixpence was a large sum in those days, but it seems to have brought in about £500 a year for some years. In 1834, the Town Council reduced the admission fee to one shilling, and in 1839 it was proposed to reduce it still further, to sixpence, though this attempt to popularise the museum does not seem to have been carried out. Jameson is said to have resisted to the last the opening of his museum to the general public, and made no effort to display the specimens in a manner that would appeal to them. No doubt he regarded the collections essentially as teaching collections, and he lacked money to pay for attendants, but he was overruled in this matter.

As the years passed, important collections from abroad were acquired, but it is impossible to follow the fortunes of the museum any further in detail. It is worth recalling, however, a statement made by Jameson in October, 1826, in giving evidence before a Royal Commission on The Universities of Scotland. He remarked "I am anxious that new accommodation should be speedily provided for the Royal Museum, which is not to be considered as a private department of the University, but as a public department connected in some degree with the country of Scotland; it is the National Museum of this country". Jameson was looking ahead.

We must pass on now to Jameson's last years and the end of the museum as a university museum. When Robert Jameson died on April 19, in 1854, in his eightieth year, he had become a feeble old man, and his lectures were read for him by an assistant. Four years before his death the British Association met in Edinburgh and Andrew Ramsay, later Director of the Geological Survey, who attended Section C (Geology), wrote in his diary "Old Jameson was there, and in the chair for a while. He looked just like a baked mummy." While his powers as a teacher may have waned, his care for the great Natural History collections in his charge had not ceased. Edward Forbes, his successor, wrote "I find Jameson's collection wonderful, even palaeontologically, and brought up by judicious purchases to the last moment". His nephew, Laurence Jameson, records that it then contained more than 74,000 specimens, with upwards of 36,000 in the zoological section, more than 28,000 rocks and minerals, and above 9000 fossils.

THE MUSEUM BECOMES A NATIONAL INSTITUTION

In 1852 Jameson prepared a statement indicating that many thousands of museum specimens could not be exhibited for want of proper accommodation. The Town Council accepted the need for urgent action, and submitted a Memorial to the Treasury, asking not only for an extension of the museum, but also that it should be converted into a National Museum for Scotland. Jameson, as Keeper, also forwarded a Memorial to the Treasury. A third petition was submitted by the Senatus of the University, who asked the Government to convert the museum into a National Collection, and to erect a building for it to the west of the College, as an addition to and an integral part of the existing University buildings. The Senatus seems to have hoped that a benevolent Treasury would also build them a new Graduation Hall as part of the new building. Fortunately, at this time, the Government, with the enthusiastic support of the Prince Consort, were interested in furthering education by various means, including museums, and the memorials met with sympathetic consideration. The offer to transfer the Natural History Museum Collections to the nation was accepted in 1854.

Lyon Playfair, writing as an official of the Board of Trade, put before the Town Council and the Senatus a scheme for creating a National Museum on the proposed site to the west of the College, the museum to be one of Natural History and Technology. The Senatus were to

FIG. 4. Title page of first volume of *The Edinburgh Philosophical Journal*, founded and edited by David Brewster and Robert Jameson. Later it was conducted by Jameson alone, as *The Edinburgh New Philosophical Journal*.

hand over their collections, and the Regius Professor of Natural History was to be the Keeper of them. A separate Keeper of Technology would be appointed.

Then, as now, the Treasury did not act without circumspection, and taking a long view. They put up the money, but they took steps to ensure that effective control of the new museum would remain in their hands. Events followed a course not quite that which the University authorities had anticipated. In 1855 a Regius Chair of Technology was founded by a Commission of Queen Victoria, and the Commission stated that the Director of the new Industrial Museum should be, *ex officio*, Professor of Technology. At that date the museum had not come into existence, but the Treasury were looking ahead. They did not wish to give the University a perpetual title to the direction of the museum.

Dr. George Wilson, an Edinburgh citizen well qualified for the post, was appointed Regius Professor of Technology during the Queen's Pleasure. He actually lectured on the subject, and made a start at collecting industrial exhibits. Unfortunately, four years after his appointment, before the new building had even been commenced, Wilson died. Immediately the Government suppressed the Chair of Technology, as they were empowered to do, and appointed an official of their own choice as Director of the museum.

A further result of the change was that the great natural history collections accumulated by Jameson were soon taken away from the University, and passed under the control of the new museum authorities. It seems to have been the original intention that they should remain accessible to the University for teaching purposes. Some years later, however, in 1871, Archibald Geikie records that on his appointment to the newly created Chair of Geology, not only were no specimens of rocks, minerals and fossils available for teaching, but there were difficulties in the way of his utilising the former Jameson collections. These consequences of the change may have caused some chagrin to the University Senatus at the time, but what the University lost the community as a whole gained. When, on October 23, 1861, the Prince Consort laid the foundation stone of the new Museum of Science and Art, now the Royal Scottish Museum, in Chambers Street, Edinburgh, it was a great step forward in the cultural life of Scotland.

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THE MOLECULAR ARCHITECTURE OF HIGH POLYMERS

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A feature of man's inventiveness and ingenuity is his ability to modify natural products and improve upon them in such a way that they better satisfy his needs. In certain respects many of these natural products are far from perfect, and in such cases a purely synthetic approach may enable us to prepare a material which represents a real advance on anything that is available in nature.

In many instances man uses natural materials for purposes widely different from the ones they were designed to meet in nature, which is one reason why they may fall short of man's requirements. An outstanding illustration of this is the use of latex from the rubber tree (*Hevea brasiliensis*) for the manufacture of motor tyres.

New and powerful techniques have been brought to bear upon the study of molecular structure, and have yielded spectacular results. A fine example of progress in this field is provided by recent advances in the study of high polymers, of which natural rubber and the artificial resins which we call 'plastics' are examples. An understanding of the relationship between structure and physical properties has made it possible to introduce a number of new products which have established themselves commercially, replacing natural products that have been in use for centuries. In the light of these researches it has also proved possible to control and modify deliberately many natural materials, so improving upon some of their desirable characteristics.

Characteristically these polymers have molecular weights which are far greater than those of simple chemical compounds. Often their molecules are built like chains (either straight chains or branching chains); a variable number of links may go into the chains of a particular polymeric substance, and several different kinds of link may be involved in the structure of one of these chains. The use of the 'chain' simile is justified by the fact that there is a linear succession of repeating units in these large molecules.

These polymers differ greatly in their properties. Some are viscous liquids; others are waxes; yet others are brittle or tough resins, fibres, or rubbers. At first sight there appears to be no correlation between their diverse properties, but in fact many of them may be explained when one has considered the three basic features: *molecular weight, chemical structure,* and *molecular shape.*

Many of the physical properties of high polymers depend on the cumulative effect of multiple molecular contacts. Thus the tensile strength, toughness and softening point all tend to increase as the number of molecular contacts increases with increasing molecular weight. For example, polymers of butadiene containing about 1000 atoms are *viscous liquids,* while those with 10,000 atoms are *tough rubbers.* No single property, however, characterises the materials. Those compounds which contain atoms of high *electro-negativity* (e.g. oxygen, nitrogen, or chlorine) in conjunction with carbon and hydrogen—termed polar compounds—show typical polymeric features at much lower molecular weights than do non-polar compounds. Rubbery or fibrous characteristics are found when one is dealing with the polar polyesters or polyamides of molecular weights of about 10,000; most hydrocarbon polymers exhibit these properties when their molecular weights are of the order of 100,000. Polar compounds usually have a higher softening point, and are therefore more suitable for making fibres or for moulding resins; in addition, they are soluble in non-hydrocarbon solvents.

If these large molecules, polar or non-polar, have a regular and compact structure, they can be readily arranged in crystal lattices. If the areas of crystallinity are randomly scattered through the material (Fig. 1), then the polymer will be either a tough or hard resin or a wax; on the other hand, if they can be given some orientation by the process of stretching or rolling (Fig. 2), a film or fibre is obtained. It must not be assumed that all the atoms lie in crystalline regions, as in inorganic crystals. Even in the well-ordered fibres, in which crystallites containing about 100 atoms occur, the amount of crystallinity usually does not exceed 50% to 70%, although higher values have been obtained. Thus long molecules may pass through many such crystallites, the regions between them, where the chain molecules cross one another or where branches and other molecular irregularities occur, being amorphous. If the regularity of the molecules is insufficient to maintain the crystalline zones intact against thermal motions, or if the cohesional properties of the molecules are low, then the material will assume a tangled configuration (Fig. 3) and will be a rubber. In this case the distance between the ends of an individual molecule is much less than its extended length, the molecule exhibiting various configurations owing to the free movement of its segments. The kinked configurations are the most probable, and when such a molecule is extended there is a restoring force because of this thermal motion of its segments. With rubbery materials it is necessary to prevent the chains from slipping past one another if the material is to retain its shape; this can be done by linking the chains together, which can be achieved by various methods.

When the molecular units are very large and of irregular shape, or when they are linked together in

FIG. 1. Unorientated crystallites; the material is resinous.
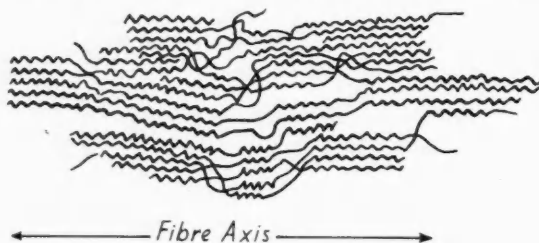

← Fibre Axis →

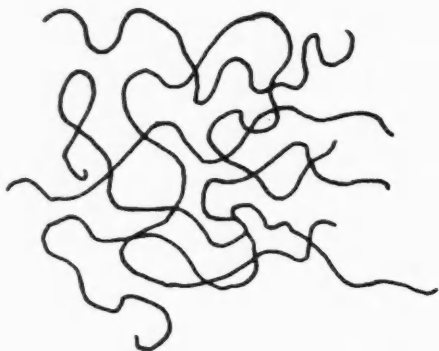FIG. 2. Orientated crystallites (Fibrous).

FIG. 3. Non-crystalline (Rubbery material).

short, much branched structures, then brittle resins which are inflexible, insoluble and infusible may result.

These are some of the general characteristics of high polymers which will be illustrated by considering some of the more important polymers in detail. In particular, emphasis will be put on the ability to change or develop desirable characteristics.

POLYISOPRENE

Two of the most important forms of natural polyisoprene are rubber and gutta percha. Natural rubber has the cis configuration shown in Fig. 4, while gutta percha has a trans configuration and exists in two crystalline forms, the β form being shown in Fig. 5.*

As would be anticipated from their shapes, the latter type of molecule fits into a crystalline lattice more readily than does the former, and in fact this form of gutta melts at about 70°C, whereas natural rubber melts at about 20°C.

The crystallisation of unstretched rubber at room temperatures is a slow process and the material often remains supercooled for long periods. However, rubber crystallises readily on stretching, a fact which is of great technical importance, since it accounts for rubber's great strength. If stretched to eight times its original length while cold, raw rubber gives a fibrous raffia-like material without elastic properties; on warming it returns to its original rubbery form, apart from a small amount of plastic flow. This 'racking' of rubber, as it is called, would be most undesirable in manufactured rubber articles, and this is prevented by 'disordering' the molecular structure by the incorporation of a small amount of sulphur atoms in the vulcanising process. When this is done, the rubber molecules only crystallise when stretched and return to their original state immediately the stress is removed. Also the sulphur by joining together individual chains prevents plastic flow of the rubber under stress or when heated.

Rubber, which under different conditions may be a tough resin, a rubber or a low melting fibre, may readily be transformed into a hard resin by treatment with strong acids which cause ring structures to form along the chains (Fig. 6). These rather bulky groups do not slide easily past one another, nor do they easily crystallise. As a result cyclised rubber is a hard, relatively high melting resinous compound.

Chemical modification of rubber by treatment with hydrogen chloride acid or chlorine (which also causes some cyclisation) gives resinous products; the effect here is that of the polar chlorine atom increasing the molecular cohesion. Rubber hydrochloride gives an attractive foil for packaging, while chlorinated rubber is useful in paints and adhesives. Finally, polyisoprenes may be readily converted to viscous liquids by reducing the molecular weight by means of oxidising agents; these liquids may then be refashioned to give a rubber-like polymer by suitable cross-linking agents.

To complete the story of polyisoprene it is necessary to mention the synthetic form, which is much less regular in shape (Fig. 7) than the natural polymers, and is rubbery. However, its irregularity is such that even on stretching it will not crystallise, and because of this fact its strength is only about one-tenth that of natural rubber.

Many of the synthetic rubbers, including the best known synthetic rubber (GR-S, which is synthesised from butadiene and styrene), exhibit this lack of mole-

* The molecular diagrams (in which 1 cm.=2·4 Å) show only the carbon atoms. Adjacent polymer chains do not lie in contact with one another, and to indicate their spatial relationship more accurately the distance of closest approach is shown for two cases (Figs. 4–5) as dotted lines.

cular regularity which gives them very poor strength. Fortunately for the users of these materials the incorporation of finely divided carbon black results in a remarkable increase in strength.

POLYCHLOROPRENE

One of the earliest synthetic rubbers—polychloroprene, which is also called Neoprene—is very regular in its molecular structure (Fig. 8). As a result of this it crystallises on stretching and possesses great strength. The introduction of a second chlorine atom at the points on the chains marked A does not affect the molecular regularity, and the molecules of Neoprene orientate and crystallise on stretching. However, their cohesion is now so great that the polymer forms fibres of high melting point.

POLYETHYLENE

Polyethylene is a tough, leathery product with a very simple structure (Fig. 9), which exhibits crystallinity and fibrous properties at quite low molecular weights, although the commercial product contains numerous branches. (In fact, molecular irregularities and the presence of mixtures of homologous compounds whose molecular lengths lie within certain limits may actually improve the physical properties of high polymers.) Polyethylene is not very reactive chemically, but by introducing bulky chlorine atoms irregularly along the chain, one obtains a strong, attractive rubber which may be set or vulcanised by use of a small proportion of SO_2Cl groups introduced at random along the chlorinated polyethylene chains. The balance of the substituents is important—if too many or too few chlorine atoms are introduced, a resin will be obtained; too many chlorosulphonyl groups will give a polymer which is difficult to process, too few will make vulcanisation impossible.

An interesting new method for modifying polymer structure is by exposing them to high-energy radiations (e.g. neutrons or gamma rays) which break some of the bonds. This bond-breaking process produces radicals which combine to give a cross-linked polymer, the degree of cross-linking being determined by the amount of irradiation. When polyethylene is irradiated a few cross-links are formed which have the effect of making it insoluble and infusible, but without breaking up a large proportion of the ordered crystalline regions. If the crystallites are melted by raising the temperature (e.g. to 120°C), the cross-linked polythene becomes rubbery and retains its shape; in fact, it is similar to a vulcanised rubber. Heavy irradiation gives a new product, many cross-links are formed, crystallinity is destroyed, and the polythene is converted into a hard polymer which is glass-like and infusible.

FIBRES

Those polymers which form fibres suitable for clothing must be highly orientated and retain their fibrous character at relatively high temperatures. They must have a regular linear structure and the cohesion between
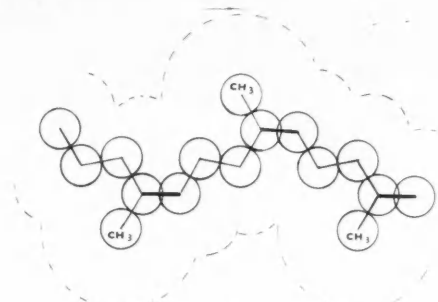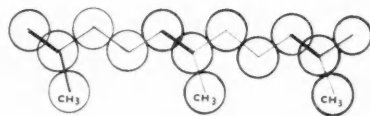

FIG. 4. Polyisoprene (Rubber).
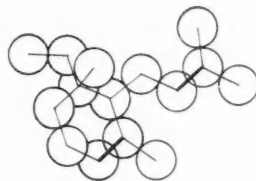

FIG. 5. Polyisoprene (β Gutta).
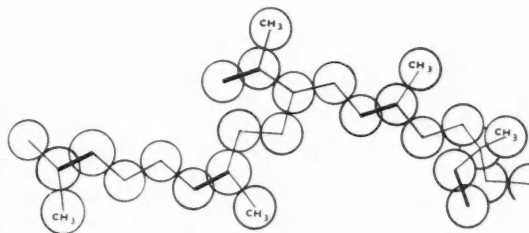

FIG. 6. Cyclised rubber.

FIG. 7. Polyisoprene (Synthetic).

the chains must be high. Synthetic polymers which meet these requirements are the polyamides (nylon and Perlon), polyacrylonitrile (Orlon), polyethylene terephthalate (Terylene); naturally occurring fibre polymers include silk and cellulose. As with rubber, cellulose may be converted into substances varying from strong, well-orientated fibres to soft, flexible rubbers or resins.

The fibre-forming properties of nylon (Fig. 10) result from a balance between the cohesion of the NHCO groups, the carbon chain, and the molecular linearity.

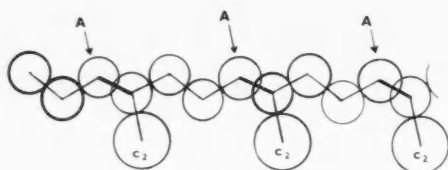If the length of the carbon chains is increased, the

FIG. 8. Polychloroprene.
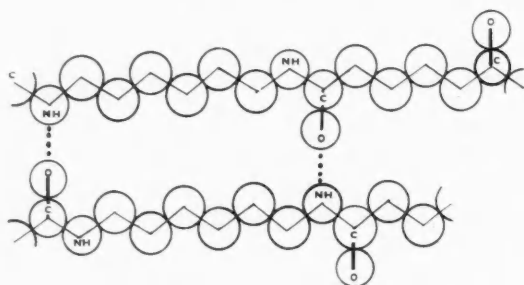

FIG. 9. Polyethylene.

FIG. 10. Nylon (6,6), showing inter-molecular hydrogen bonding.

material will still be fibre-forming, but the melting point will be lower. If side groups are introduced along the carbon chains, the fibre-forming properties will be reduced or even destroyed. Substitution of the amide hydrogen atoms by alkyl groups gives a softer, lower melting polymer. As the degree of alkylation is increased, the nylon-type polymer becomes a rubber, and finally a viscous liquid results when all the amide groups are substituted.

The conversion of these highly polar resins into fibres requires a mechanical operation (e.g. drawing) to orientate their molecules. This illustrates the use of a physical process as distinct from chemical reactions. Other physical changes (e.g. the addition of plasticisers to reduce the strength of the intermolecular contacts; changes in temperature) may have equally striking effects. Thus polystyrene is a tough resin at room temperatures, but it becomes a rubber above 120°C; natural rubber itself is a tough resin below −60°C. It is important to realise that some orientation may occur when polymers are stretched without observable crystallinity being found by X-ray methods of examination; this is true for polystyrene where the bulky chains prevent fitting into a crystal lattice. Polyvinyl acetate also shows no crystallinity, but when it is hydrolysed to polyvinyl alcohol the small size of the hydroxyl groups and their strong attraction for one another causes it to be crystalline; it is then fibrous in character, and has thus found use as a water-soluble suture in surgery.

COPOLYMERS

Besides changing polymer characteristics by chemical or physical modification, it is possible, in addition, to synthesise polymers containing groupings which confer desirable properties. For example, if a polymer is too hard, will not vulcanise or dissolve in suitable solvents, it is possible to incorporate, or copolymerise, other molecules into the macromolecule which will produce the desired effect. Examples of this are the copolymers of vinyl acetate and vinyl chloride (Vinyon) which are softer than vinyl chloride alone, the copolymerisation of isoprene with isobutylene to enable a heat- and oxygen-resistant rubber to be vulcanised, and the incorporation of maleic anhydride into polyvinylacetate in order to improve its adhesion to metals. In fact, the synthetic polymer of greatest importance at the present time is a copolymer of butadiene with styrene. The styrene, here used in minor amounts, improves molecular linearity of the copolymer and the physical properties of the final rubber.

Other groups of polymers with interesting properties are the polyacrylates and polymethacrylates, the best known of which is polymethyl methacrylate (Perspex). In these polymers there is a balance between the polar character of the carbonyl group and the shielding action of the non-polar alkyl group. For example, in the acrylates

$$\left[-CH_2-CH- \atop \quad\quad | \atop \quad\quad COOR \right]_n$$
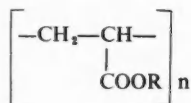
when R is a hydrogen atom, the polymer is a hard, brittle resin (Plate 1), while if R is a methyl group, the polymer is a tough leather. Polyacrylates with alkyl groups containing two to six carbon atoms (Plate 2) are rubbers, while those with alkyl groups containing eight carbon atoms are viscous liquids.

In these models the black rods represent the main carbon chain, the black portions are carbon atoms, white spheres are hydrogen atoms and the shaded portions oxygen atoms. The polar oxygen atom which gives the high cohesion is marked with an arrow and a bracket is drawn round the shielding alkyl group.

With very long carbon chains the characteristic properties of the polyacrylate tend to disappear and the polymer tends to become more like a hydrocarbon. These remarks, however, apply only to linear carbon chains, for if the alkyl groups are very irregular, the steric restriction on rotation has a greater and opposite effect than the reduction of the molecular cohesion. To illustrate this, poly n-butyl acrylate (Plate 3) is a soft, resilient rubber, while poly ter-butyl acrylate is a hard resin (Plate 4), although the alkyl groups have the same size.

The most recent developments in the 'tailored molecule' are the 'graft' and 'block' polymers. In these relatively large segments of different polymers are
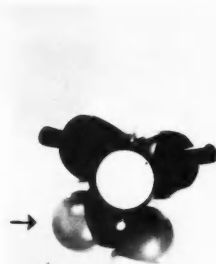
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ACID

PLATE 3
POLY N-BUTYL
ACRYLATE

PLATE 2
POLY N-HEXYL
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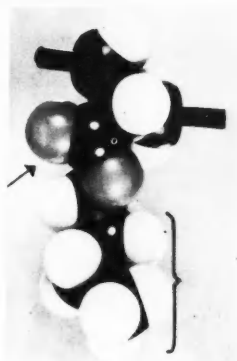
PLATE 4
POLY TER-BUTYL
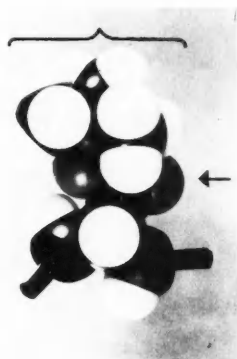ACRYLATE

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linked together. If they are joined end-to-end, it is termed a block polymer, while if branches of one polymer are introduced along the molecular chain of another polymer, then it is a graft polymer. There are many ways of producing these substances, and if the two types of polymer are of widely different character, very interesting polymers may result. If the segments of the different polymers are of a suitable size then the copolymers display properties which are to some extent a combination of the properties of the individual polymers rather than an average. The introduction of water-soluble chains into an oil-soluble polymer, for example, may give it unusual surface properties—such as antistatic character or ready dyeing—or even the character of a detergent.

Most of the polymers discussed above have been compounds whose length is great compared with their breadth. Molecules of large size and irregular shape generally give brittle resins and they are usually difficult to build to great size. Certain simple molecules, such as phenol, or urea and formaldehyde, or divinylbenzene, build up a highly ramified three-dimensional network of relatively small mesh. In these cases the properties are readily explained. The tight network prevents much movement of the individual parts either by heat or solvents, and as a result they are hard, inelastic,

infusible, and insoluble. Here again it is possible to control their molecular architecture with some success. The polyester from glycerol and phthalic acid is a hard, infusible resin, but by incorporation of castor oil, which reacts with some of ·the acid groups, tough, flexible polymers suitable for paints may be formed. Urea-formaldehyde resins are normally hard, insoluble, and infusible, but by blocking (during the preparation of the resins) some of the reactive groups with benzyl alcohol, a process which reduces the number of cross-links formed, flexible resins are obtained which are suitable for stoving enamels.

The above account has dealt with a few of the bewildering variety of materials which have been developed in recent years. Many of them have found a lasting importance; it is, however, true to say that notwithstanding the advances which have been made, no single polymer possesses wholly desirable properties. In most cases an improvement in one property is accompanied by an undesirable change in another and it is usually necessary to compromise between the two. Efforts continue to gain closer control over molecular structure, and to this end every weapon in the armoury of the scientist is used. Great advances are being made, but the ultimate goal of the uniquely tailored molecule lies far ahead.

"DEEP FREEZE" CAN REVOLUTIONISE ARTIFICIAL INSEMINATION

CHAPMAN PINCHER

A British bull is still fathering calves although it has been dead for eighteen months. The calves are normal in every way. Veterinary scientists at a Cambridge artificial insemination centre took semen from the bull and stored it in a 'deep freeze' before the animal died, and this semen is still being used to inseminate cows, with excellent results.

Human corneal tissue is being used successfully for transplantation in eye operations a year after the death of the donors, and human red blood cells are being used for transfusion after many months in store.

These astonishing developments, like so many others which have proved to be of profound importance, resulted from a discovery which was made accidentally. Scientists, led by Dr. A. S. Parkes, at the National Institute for Medical Research at Mill Hill, London, were investigating the effects of very low temperatures on sperms—the male fertilising cells of animals. As they expected, they found that freezing and thawing always killed the sperms of mammals and birds, and they therefore sought ways of avoiding this effect in the hope that it would thereby be possible to store sperms for long periods at low temperatures in a state of suspended animation.

In the course of this work some glycerine was mixed with poultry semen, which was being examined by Dr. Parkes and his colleagues Dr. Audrey Smith and Mr. Christopher Polge.

The scientists were surprised to find that somehow this substance protected the sperms so that if they were frozen down to the temperature of 'dry ice' (solid carbon dioxide), which is minus 79°C, most of them revived completely when they were thawed out again.

They were soon able to prove that sperms which had been frozen in this way could fertilise eggs and produce quite normal chicks.

They immediately realised that this finding might mean an advance of the greatest significance for agriculture if the sperms of farm mammals like bulls, rams and stallions survived freezing as readily as those of poultry. So Dr. Parkes's team started an investigation with bull semen. They found that bull sperms were not as tough as those of the fowl and required to be cooled slowly even in the presence of glycerine. Later on in 1951, aided by L. E. Rowson, director of The Cambridge and District Cattle Breeding Centre, they successfully froze bull sperms, which produced normal calves when thawed out and introduced into cows by the usual process of artificial insemination.

Out of 38 cows inseminated with the thawed-out sperms, 30 conceived and 24 of them produced normal calves—a high rate of fertility for cattle. In a later test involving 3281 cows, a conception rate of 78% was obtained—compared with 76% when ordinary natural sperm was used.

Bull sperms have now been stored for *19 months* in vacuum flasks containing 'dry ice' without any appreciable loss of fertilising power. There seems to be no reason why they should lose their activity if stored for much longer periods.

Large stocks of bull sperm have been put aside for tests at subsequent dates—some of them scheduled for many years ahead.

One experimental store built at Cambridge can hold enough sperms frozen at −79°C to inseminate 50,000 cows for a storage cost of only £2 a week.

What are the immediate advantages of this development?

(1) A farmer should now be able to *nominate* semen from a particular bull he favours. So far a farmer using an artificial insemination centre has had to be content with the semen available on the day when his cow was ready for service. Now he should be able to nominate any particular bull at the centre or, for that matter, anywhere in the country or even in the world if the owner were willing.

Most of the artificial insemination centres have already adopted the freezing of semen as a practical proposition and are offering insemination from nominated sires.

Being able to freeze sperm greatly facilitates the day-to-day work of the artificial insemination centres because hitherto semen had to be used within a day or so.

(2) It should be possible to export semen to foreign countries instead of exporting pedigree farm stock. The semen could be held in quarantine until it was certain that the animal from which it came was not suffering from any infectious disease at the time the semen was collected.

Frozen semen has already been successfully exported in experimental quantities from Britain to Brazil and South Africa and appeared to have arrived in perfect condition.

The commercial export of semen raises major difficulties of policy which will have to be considered by the Breed Societies and pedigree breeders, and will no doubt involve Government action. Meanwhile at least one Breed Society has ruled that when a breeding bull is sold for export any stocks of frozen semen must go with it. This is to prevent any breeder 'laying down a cellar' of semen from a good bull and then selling the animal.

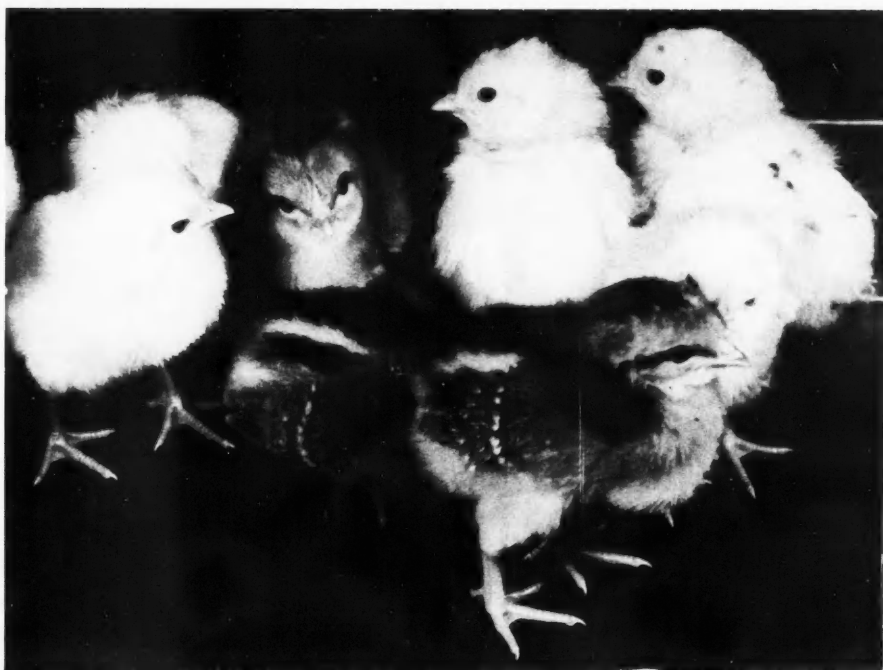(3) In countries like New Zealand where nearly all the cows calve in two months in spring, semen could be

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FIG. 1. Chicks hatched from eggs fertilised by frozen sperm.

collected throughout the year and used during the two months when it is required.

(4) If bull sperm proves to remain active after five years of storage it may be possible to effect a really substantial improvement in the milk yield of British dairy herds. The keeping of milk records has proved that an impressive pedigree is not a reliable guide to a bull's capacity for begetting cows with a high milk yield. The only sure guide is to test some of the bull's female offspring before breeding from it on a large scale. This practice is difficult to follow because at least 2–3 years must elapse before any significant milk records of a bull's offspring are available and the reproductive life of the animal is often short.

The freezing of semen may get round these difficulties. The bulk of the semen from bulls could be kept in store until its worth in producing cows characterised by high milk yield had been evaluated. Then the semen which had proved to be valuable could be used to the full while the semen of mediocre genetic quality could be destroyed.

Technically it should be possible to inseminate all the animals in Britain by sperm from about 100 proved bulls.

The need for such a development is shown by the fact that artificial insemination as operated so far has failed to improve the yield of British dairy herds significantly.

The technique would clearly be applicable to other domestic animals. There will undoubtedly be policy objections to using it in the case of thoroughbred horses but the possibility of raising the quality of British pigs by artificial insemination from proved boars is under consideration.

Biologists are also taking advantage of the Mill Hill discoveries for fundamental research purposes. For example, marine biologists at Aberdeen have now been able to cross two different races of North-East Atlantic herrings, a feat which was impossible before because one race spawns in the spring and one in the autumn. Ripe sperms taken from the spring-spawning herrings were frozen in March. They were then thawed out in September and used to fertilise eggs taken from autumn-spawning herrings. As with bull semen, fertility was high.

The idea of applying such methods to produce human births is repugnant to many since it raises religious as well as social and legal issues, but the fact must be faced that sooner or later they will be applied somewhere in the world perhaps on a large scale. Indeed, the first steps have already been taken.

The scientists at the National Institute for Medical Research showed that human sperms can survive freezing especially if protected by glycerol. Now U.S. doctors have taken the process a stage further. Three women have been successfully inseminated at an Iowa hospital with sperms which had been frozen. They all became pregnant.

If the children are normal at birth—and there is no reason to doubt that they will be—scientists will undoubtedly try the effect of inseminating women with sperms stored for months and later for years. (It might be thought that the bare possibility that freezing might

FIG. 2. Fertilised rabbit egg, divided after having been frozen to −190°C for 24 hours in glycerol-serum.

cause inheritable damage to the sperms which might result in the production of a defective child, would rule out the process for human application. However, it should be borne in mind that a similar risk is regularly accepted in the exposure of sperms to chemical spermicides in sub-lethal concentrations.)

What possible useful purpose could such experiments serve?

In the first place, they would reduce the difficulties of doctors who require semen for the insemination of women whose husbands are incapable of having children. Semen from anonymous donors could be kept in store and used when required at any time. But much more spectacular developments can be foreseen.

If human sperms can be successfully stored for years it should be possible for young men to 'bank' sperms against the misfortune of becoming infertile in later life. Husbands separated from their wives for long periods would be able to father legitimate children.

It must not be thought that all the technical problems of utilising stored semen have been solved. For instance, for very long periods of storage—the scientists themselves are already talking about 'tens of years'—temperatures lower than −79°C may be necessary. Experiments on storage at the temperature of liquid air, −192°C, are in progress.

It seemed likely that the glycerol technique could be applied to the storage of other living cells in the frozen state. The first effect of freezing is that water rapidly crystallises out of the surrounding medium and cell fluids as ice, and the salts remaining in the residue become so concentrated that the cells are 'pickled in their own brine'. One of the chief actions of glycerol is to mitigate this effect. So the Mill Hill scientists quickly turned their attention to the possibility of freezing red blood-cells in glycerol—an investigation of obvious practical significance.

Dr. Audrey Smith was able to show that when human blood is protected by glycerol the red cells are not destroyed by freezing and thawing as had always happened previously. Following up this demonstration, Dr. H. A.

Sloviter, a U.S. scientist then at Mill Hill, found that rabbit red blood-cells which had been frozen and thawed behaved normally when injected into the bloodstream of a living animal. Later (in 1951) in conjunction with Dr. P. L. Mollison he was able to show that human red blood-cells which had been frozen, thawed and then slowly freed from the glycerol survived normally after transfusion into patients.

These experiments have opened the way to the indefinite storage of whole blood by refrigeration, which carries enormous military as well as civil advantages.

Long-term storage will be of especial value in the case of rare types of blood which, though needed only occasionally, are usually needed in a hurry. Before these developments whole blood could not be safely stored for longer than four weeks.

Dr. Smith also eventually developed a technique for storing fertilised rabbit eggs at low temperatures. Eggs removed from does were slowly frozen in a medium containing glycerol. After they had subsequently been thawed and cultured some of them began to divide normally. If the eggs of farm mammals can be stored in this way, the process may have important practical application to the system of transplanting eggs which enables one female to serve as an incubator for another female's offspring*.

While exploring methods of storing rabbit eggs, Dr. Smith and Dr. Parkes found that ovarian tissue readily survives freezing if it is protected by glycerol. They were able to get such cells to multiply in tissue-culture after freezing and thawing. Later they were able to show that such tissues taken from rats and frozen for long periods—two years is the present record—can be successfully grafted back into rats from which the ovaries have been completely removed and will retain their power to produce sex-hormones.

In their report of these experiments, published, significantly, in a medical journal, the scientists pointed out that human hormone-producing tissues might be stored this way, with obvious clinical advantages.

Promising work with the freezing of adrenal gland and other tissues is in progress.

The successful preservation of corneal grafts for eye operations by freezing in media containing glycerol has been recently announced. Under previous methods of storage in eye 'banks', human corneal tissues could be kept for only a few days. A team at St. Mary's Hospital, London, has kept such corneal tissues for nine months by the glycerol deep-freeze method and has then used them on human patients with results as good as those obtained with fresh material.

All these developments with their far-reaching theoretical implications and practical possibilities, stem from a fundamental research programme on the effects of physical and chemical agents on reproductive cells planned and put into operation by Dr. A. S. Parkes at the National Institute for Medical Research ten years ago.
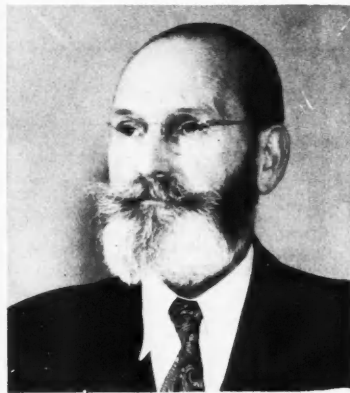
* See article Transplanting Mammals' Eggs, DISCOVERY, Feb. 1948, pp. 52–3.

Dr. Archibald Clow, producer of the B.B.C.'s "Science Survey", has just celebrated his 250th programme.

Sir George Allen, new secretary of the British Association; formerly vice-chancellor of the University of Malaya, Singapore.

Mr. Frederick D. Edwards, founder and managing director of the world famous vacuum firm (see below).

FAR AND NEAR

Night Sky in April

The Moon.—New moon occurs on April 3d 12h 25m, U.T., and full moon on April 18d 05h 48m. The following conjunctions with the moon take place:

April

1d 18h	Mercury in conjunction with the moon	Mercury	7° S.
4d 18h	Venus	„	Venus	6° S.
8d 03h	Jupiter	„	Jupiter	3° S.
19d 05h	Saturn	„	Saturn	8° N.
23d 17h	Mars	„	Mars	1° N.

The Planets.—Mercury is too close to the Sun to be favourably observed during the month. Venus is an evening star, its times of setting on April 1, 15 and 30 being 19h 50m, 20h 35m and 21h 20m, respectively. The visible portion of the illuminated disk varies from 0·967 to 0·929 and the stellar magnitude from −3·4 to −3·3. The increase in brightness in spite of the decrease in the visible portion of the illuminated disk is due to the fact that the planet is approaching the Earth, its distances on April 1 and 30 being 153 and 143 millions of miles, respectively. Mars rises at 1h 15m, 0h 50m and 0h 10m on April 1, 15 and 30 respectively. It lies rather low in the constellation Sagittarius through which it has an eastward movement which carries it just N. of λ Sagittarius towards the end of the month. During April its stellar magnitude varies from 0·1 to −0·6, the increase in brightness being due to its approach to the Earth, from 89 to 66 millions of miles during April. Jupiter sets at 0h 50m on April 1, at midnight at the middle of the month, and at 23h 15m on April 30, stellar magnitude −1·7 to −1·6. Its eastward movement from the

west to the east of ζ Tauri is easily seen during the month. Saturn rises at 20h 50m, 19h 50 m and 18h 40m on April 1, 15 and 30, respectively, and is visible during the night close to × Virginis.

The Lyrid meteors are most active from about April 20 to 22 but moonlight will prevent observations of the shower except in the earlier part of the night. These meteors are the debris of Comet 1861 1 and are called the Lyrids because they appear to emanate from a small area near the constellation Lyra—actually it is in the neighbouring constellation Hercules so that, strictly speaking, they should be called the Herculids but the name Lyrids has been in use so long that it is very improbable Herculids will ever replace it. This shower is not a very active one, the normal hourly rate being less than 10, which is much below that of some of the other well-known showers.

A New Method for Revealing Fingerprints

A new technique for registering fingerprints has been developed by two Swedish scientists connected with the Institute of Biochemistry, Uppsala. It depends on the presence of amino-acids in sweat, and the fingerprints are simply developed by spraying with a 0·2% solution of ninhydrin in acetone, followed by heating in an oven at 80°C for a few minutes. This method has proved effective for bringing out fingerprints on paper that has not been touched by human hand for as long as twelve years. The new method is reported in *Nature* (March 6, 1954; p. 449).

The latest Smithsonian Annual Report: Swarming of Grasshoppers and Locusts

The appendix to the latest annual report of the Smithsonian Institution of Washington includes a DISCOVERY article—"Phosphorus and Life," by D. P. Hopkins, which we published in March 1952. The only other British contribution to this 460-page volume is the Friday evening Discourse of J. A. Ratcliffe on Radio Astronomy.

One of the most interesting articles in this book deals with the Grasshopper Glacier of Montana, which contains large numbers of frozen and well-preserved grasshoppers. The most important species is apparently *Melanoplus mexicanus mexicanus* (Saussure). In 1949 numerous specimens of a related grasshopper (*Melanoplus rugglesi*) was found *alive* on the snowfield of the glacier; investigation showed that these insects were probably brought by air currents all the way from either Oregon or Nevada.

The glacier is nearly 11,000 ft. above sea level, and a mile or so in width. Grasshoppers appear to have become embedded from top to bottom of the glacier. Sometimes when the snows melt piles of grasshoppers two to four feet deep are found 'smelling to high heaven'. The question is being asked whether the preserved insects found in the ice at the bottom of the glacier date back to the Pleistocene (say 11,000 years ago) or soon after. This problem is being tackled by the carbon 14 method of dating organic remains.

Up to 1949 the gregarious phase of *M. rugglesi* was known only in N.W. Nevada, N.E. California and S.E. Oregon—in any case at a distance of at least 500 miles from Grasshopper

Glacier. A Weather Bureau expert came to the conclusion that winds at an altitude of 10,000 ft. above sea-level could have carried the grasshoppers from S.E. Oregon to the glacier *if the insects were able to reach that altitude.* One report of a grasshopper swarm was obtained from an airline pilot who was flying at the time in the relevant region.

In the case of the African desert locust *Schistocerca gregaria* similar long-distance 'migration' has been recorded. For instance, in Oct. 1945 many specimens of this locust reached Portugal. Expert opinion came to the conclusion that these insects originated in W. Morocco, which they probably left on the morning of Oct. 11, arriving over Portugal late that night or the next day. The distance involved was 600–800 miles, varying with the different spots in Portugal where they were found. The morning of Oct. 11 was marked by a sharp rise in temperature inducive of flight activity, accompanied by convection currents and a wind blowing out to sea. A few miles off-shore a strong wind from the south, averaging about 30 m.p.h. at 1500–2000 ft., was blowing.

It is argued that the reactions of *M. rugglesi* are likely to resemble those of the locust species just mentioned. Probably, at irregular intervals, for centuries past swarms of the grasshoppers have been carried long distances when the appropriate aerodynamic conditions have existed in the atmosphere. Information about such incidents is likely to be obtained from further work on Grasshopper Glacier and other glaciers.

Other deposits of frozen grasshoppers are known, for instance a second 'grasshopper glacier' in the Beartooth Range. Another site near Grasshopper Glacier was found in 1899 on the slopes of Mt. Dewey; here perfectly preserved specimens were obtained, the ice being stationary and therefore giving especially good conditions for the survival of intact grasshopper bodies. In 1934 a dead swarm of the locust *S. gregaria* was discovered in the saddle of Mt. Kilimanjaro in Africa, and Shipton in his book *Upon that Mountain* reported hundreds of grasshoppers which he found embedded in the bare-ice surface of a glacier at over 16,000 ft. on Mt. Kenya in 1929.

As the author of this article (A. B. Gurney of the U.S.D.A., Bureau of Entomology) says, Grasshopper Glacier is an exceptional freak of nature that should yield basic facts about the movement of insects by air currents and glacial preservation of insects.

Element 100

Time reports the discovery of Element 100. This has been synthesised by 'fattening' atoms of Plutonium 239 (94 protons, 145 neutrons) in the materials testing reactor at Arco, Idaho. The plutonium atoms absorbed 15 neutrons and emitted 6 beta particles (electrons). Since a neutron minus an electron equals a proton, the net result was Element 100 (100 protons, 154 neutrons). This newly discovered element has a half life of three hours. It has no name so far, and no foreseeable uses.

Edwards: Synonym for Vacuum

The new Allendale works of W. Edwards & Co. (London) Ltd. at Crawley, Sussex, was officially opened on March 5. In the course of his speech at the lunch which formed part of the ceremony Prof. E. N. da Andrade, F.R.S., told of his first meeting with the founder of the firm, Frederick Edwards. He said that "some 30 years ago, a handsome and energetic young man might have been seen passing rapidly through the back streets of Denmark Hill in search of Allendale Road, where a Mr. Edwards had an assortment of second-hand scientific apparatus for sale. The young man was me. I found the address, picked up the bottle of milk which was outside the door, and with this proof of goodwill, was admitted by, I believe, the only member of the staff to the presence of Mr. Edwards.

"I was impressed with his energy, knowledge, acumen and determination-to-get-on-ness. We talked about apparatus in general. I think that I regretted that all the best vacuum pumps were made by Germans. Mr. Edward's energy and acumen are the same; his knowledge has increased; he has got on, and the best vacuum pumps are no longer made by Germans."

Prof. Andrade continued: "The connexions between vacuum and Messrs. Edwards are so close that the words are today synonymous. When I was a schoolboy, the ordinary vacuum pump was practically in the state in which Francis Hawksbee left it in 1709. There were, it is true, hand-operated mercury vacuum pumps, but they were very, very slow and required expert handling.

"When I was in Heidelberg as a young man, the only good mechanical pump was a German Gaede pump. When, later, I was in Cambridge, there were two Gaede pumps in the Cavendish laboratory to serve some 35 research men, and both were reserved for honoured seniors, who had been there five years or more. This was just before World War I. Then the high vacuum pump was almost entirely an academic apparatus, a tool of the now somewhat decried professors who were doing physics just for fun, and because they liked finding out. Today it is of immense industrial and technical importance, essential in nuclear research, in preparing blood plasma and for all the important purposes to which our attention has been directed. And what is all this vacuum apparatus for—to produce nothing at all, shut up in a jar. The firm of Edwards make the finest apparatus in the world for producing as near nothing as possible, and we—technologists, scientists, manufacturers and businessmen—are all profoundly grateful to them."

THE BOOKSHELF

A Field Guide to the Birds of Britain and Europe.

By Roger Peterson, Guy Mountfort & P. A. D. Hollom (*London, Collins, 1954; 318 pp., 25s.*).

This book can be recommended without any qualifications whatsoever; it is a little masterpiece. 551 species are described and, better still for the amateur, most of them are illustrated in colour. In addition, opposite each plate of pictures is a table setting out the *diagnostic* characters of the various species shown in the plate. Somehow or other, the authors have contrived to find room for distribution maps of some migratory birds. It only needs to be added that the book is a pocket book and that it will be useful anywhere in Europe.

Dictionary of Organic Compounds

Edited by Sir Ian Heilbron, H. M. Bunberry and others. *4 volumes (containing 654, 845, 838 and 694 pp. respectively).* (*London, Eyre & Spottiswoode, 1953; £28 the set.*)

This dictionary first appeared as a three-volume set over the years 1934–7. To publish a completely new four-volume edition all at once is a considerable achievement for publishers and editors. Since references continue right up until the early months of 1953, precise planning must have governed every stage of the work. The result considered simply as an exercise in book production is satisfying. The double columns of print are clear and surprisingly elegant in view of the varieties of type required and the difficulties of setting constitutional formulae. The binding can be guaranteed to allow any page to remain flat when a volume is opened.

The stumbling-block in the way of any work like this is *nomenclature.* This has been overcome by using the common names of compounds with generous cross-references to systematic names. The result is a really handy reference book which will give an answer in a very short time. For the specialist, nothing can take the place of Beilstein, but to anybody else—in school, laboratory or works—this work will be found invaluable. It does exactly what it sets out to do; to give the constitution and physical and chemical properties of the principal carbon

compounds and their derivatives, together with the relevant literature references. A work like this represents not merely a purchase but an investment.

F.E.W.

Radioactivity and Radioactive Substances

By Sir James Chadwick (*London, Pitman, 1953, 120 pp., 12s. 6d.*)

This is the fourth edition of what must surely rank as a little classic. The first edition had a complimentary foreword by Lord Rutherford. The fourth edition is revised and brought up to date by Professor J. Rotblat. There is really little further to say. It is an essential book for every library in school and university, essential because of its authoritative quality. Young readers may need to be reminded that Sir James Chadwick worked with Rutherford and actually took part in some of the discoveries of atomic physics, being himself the discoverer of the neutron; so he writes about a subject that he knows at first hand. And he writes concisely and to the point, as does Professor Rotblat. The text is a simple one with the mathematics reduced to simple formulae understandable to anyone who has coped with elementary mathematics at school. Modern methods of measurement, including that using photographic emulsion, are in this new edition, as is an entirely new chapter on nuclear structure.

A book for every intelligent person who really wants to know what radioactivity is all about.

C. L. BOLTZ

The Principles of Electronics

By L. T. Agger (*London, Macmillan, 1593, 340 pp., 18s.*)

Unless the DISCOVERY copy is a freak, the publishers will have to recall all their first issue of this book, for there are eight pages completely blank. Pages 106 and 107 can perhaps be missed, for they form the end of Chapter VIII and should contain the remaining exercises on that chapter, but pages 110, 111, 114, 115, 118 and 119 are all in the chapter on multi-electrode valves and are therefore of great importance.

It is not difficult to assess the quality of the book as it would be if complete. It is a very good basic textbook on electronics; that is to say, on thermionic valves and their circuits. Starting with elementary atomics and electron dynamics it proceeds through thermionic emission and conduction through gases to the diode. Rectification, the triode, amplification and the rest follow in expected sequence, with final chapters on the cathode-ray tube and photocells.

This is a book on basic principles. Nobody will find here circuits for very special purposes. There is nothing about computers, radio receivers and transmitters, radar or electronic tortoises. There is a bare mention of oscillations at frequencies that give centimetric waves. These omissions are deliberate, the author's purpose being to give a basic course in electronics. To this end he has provided at the end of every chapter a very full set of exercises. No particular examination standard is aimed at but the final revision exercises are taken from A.M.I.E.E. and C.G.L.I. and London University degree examination papers. All the text mathematics is simple. Two particularly useful mathematical analyses are relegated to appendices.

Apart from the unfortunate mishap mentioned, the book is well printed, well illustrated and well produced. It is the sort of textbook for which there has long been a great need.

C. L. BOLTZ

Oil

(*London, Cassell, 1953, 120 pp. 8s. 6d.*)

This is the first volume in a new series dealing with British Industries, and it will serve to give young people a good idea of the scope of the oil industry. The photographs are remarkably good and very well reproduced.

Possibly the publishers might be well advised to depart from the anonymous authorship, a system which is not calculated to make most writers produce their best work; it is, moreover, generally true that authors are far more careful about recording and checking facts if their name appears on the book and they are held personally responsible for any inaccuracies which get published. Anonymity sometimes encourages forthright authorship, but only very rarely does accuracy benefit from this practice.

LETTER TO THE EDITOR

Science and The Press

Sir,

There has recently been a discussion in DISCOVERY on scientists and the Press and I should like to contribute a few remarks.

It has been rightly emphasised that the scientists have a duty to communicate the results of scientific investigations to the general public and that as a whole they are failing to do so. In my opinion there are two main reasons which spoil the relations between scientists and the Press.

The first one is the very poor reporting on scientific matters in most of the daily papers. It is all too obvious that—with a few exceptions—the reporter has only a very faint understanding of what he is writing about. Moreover, he generally only picks out items which can be given a sensational headline. May I mention a recent experience of mine which shows that even the best papers are failing in this respect? Some weeks ago I gave a lecture on Power from Atomic Energy. One of our leading newspapers, which was given a copy of the lecture in full, reported on *one* item only (on which I spent not more than *three minutes* in *an hour's* lecture) namely, some remarks concerning the question of freedom of information—and in addition this was given a rather misleading headline. There was not a word about all the other parts of the lecture containing my main conclusions, which were all of much greater importance to the problem of atomic power than the one selected. Such experiences naturally are not conducive to a harmonious relationship between scientists and the Press.

The second point concerns the right of editors to change articles written at their request. It is only very rarely that articles by daily newspapers, into which the author has put a lot of thought and work, are printed in the same form as he has written them. The editor generally 'improves' them, for instance by rearranging items, or by leaving parts out altogether, though they are important for the train of thought and so on. No scientist wants to see his name appear over an article presented in a mutilated and often misleading form. After one such embarrassing experience, the scientist is quite rightly shy of any further contacts with the Press.

The editor has still enough influence; it is he who chooses the author, he can refuse the article if he thinks it unsuitable, or he can ask for it to be shortened or changed. But under no circumstances should he be allowed to print something *under the name of the author* without having his consent to any alteration. It is often held that such a request is asking for the impossible. I should therefore like to mention that over a few years I contributed about 25 articles on scientific matters to another newspaper of high standing. After I had expressed my mind rather vigorously in the beginning, it has all worked very well indeed. My contributions have gone to print unchanged, both the editor and myself have been satisfied and happy relations have prevailed between us.

If the Press generally could accept these obvious conditions, I believe that they would find a fair number of serious scientists prepared to write for them. With closer contacts established in this way, an improvement in the quality of scientific reporting would also follow quite naturally.

I am, etc.,

(PROF.) F. E. SIMON.

Clarendon Laboratory,
Oxford.

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